4.5 PSP Cover Sheet

Proposal Title: **Real-Time Forecasting of Contaminant Loading from the Panoche/Silver CreekWatershed to the San Joaquin River**

Applicant Name: U.S. Department of Energy for Performance at Lawrence Berkeley National Laboratory

Mailing Address: c/o Sponsored Projects Office, MS-936B, One Cyclotron Road, Berkeley, CA 94720

Telephone: 510-486-6618
Fax: 510-486-4386
Email: pmgale@lbl.gov

Amount of funding requested: $ 628,378 over 2 years

Indicate the Topic for which you are applying (check only one box).
Fish Passage/Fish Screens   Introduced Species
Habitat Restoration   Fish Management/Hatchery
Local Watershed Stewardship   Environmental Education
X Water Quality

Does the proposal address a specified Focused Action? __**X**__ yes _____no

What county or counties is the project located in? **Fresno**

Indicate the geographic area of your proposal (check only one box):

Sacramento River Mainstem   East Side Trib:
Sacramento Trib:_____   Suisun Marsh and Bay
X San Joaquin Trib: **Panoche/Silver Creek, Mud Slough, Salt Slough**
Delta: _____   Other: _____

Indicate the primary species which the proposal addresses (check all that apply):

San Joaquin and East-side Delta tributaries   fall-run chinook salmon
Winter-run chinook salmon   Spring-run chinook salmon
Late-fall run chinook salmon   Fall-run chinook salmon
Delta smelt   Longfin smelt
Splittail   Steelhead trout
    Green sturgeon   Striped bass
X Migratory birds   All chinook species
Other: _____   **X** All anadromous salmonids

Specify the ERP strategic objective and target (s) that the project addresses. Include page numbers from January 1999 version of ERP Volume I and II:

Strategic Plan Goal 5, Objective 6, p. 478, Target Site is Stage 1 Expectations, p. 479. Strategic Plan Goal 6, Objective 1, p. 506, second Strategic Plan Goal 6, Objective 2, third Strategic Plan Goal 6, Objective 3, p. 507, Target Site is Stage 1 Expectations, p. 508.

Indicate the type of applicant (check only one box):

State agency			Federal agency
Public/Non-profit joint venture			Non-profit
Local government/district			Private party
University		X	Other: **National Laboratory**

Indicate the type of project (check only one box):

Planning		X	Implementation
Monitoring			Education
Research			

By signing below, the applicant declares the following:

1.) The truthfulness of all representations in their proposal;

2.) The individual signing the form is entitled to submit the application on behalf of the applicant (if the applicant is an entity or organization); and

3.) The person submitting the application has read and understood the conflict of interest and confidentiality discussion in the PSP (Section 2.4) and waives any and all rights to privacy and confidentiality of the proposal on behalf of the applicant, to the extent as provided in the Section.

Phyllis M. Housel Gale

_____
Printed name of applicant

_____
Signature of applicant

Real-Time Forecasting of Contaminant Loading from the
Panoche/Silver Creek Watershed to the San Joaquin River

PRIMARY CONTACTS:

Dr. Norman L. Miller
Regional Climate Center
90-1116, One Cyclotron Road
Lawrence Berkeley National Laboratory
Berkeley, CA 94720

Dr. Nigel W.T. Quinn
90-1116, One Cyclotron Road
Lawrence Berkeley National Laboratory
Berkeley, CA 94720

PARTICIPANTS and COLLABORATORS:

Mr. Morris (Red) Martin
Manager of Westside Resource Conservation District

Ms. Nettie Drake
Coordinated Resource Management Program
3763 E. Robinson Rd.
Fresno, CA 93726

Dr. Fred Charles
McGulley, Frick and Gillman, Inc.
71 Stevenson St., Suite 1450
San Francisco, CA 94105

Mr. Chris Eacock
U.S. Bureau of Reclamation
Fresno, CA

EXECUTIVE SUMMARY

Real-Time Forecasting of Contaminant Loading from the Panoche/Silver Creek Watershed to the San Joaquin River

Water quality in the San Joaquin River is affected by runoff and sediment contaminant loads from west-side ephemeral streams. Measures to limit these contaminant loads including early-warning systems of significant runoff events can help to reduce the impact on San Joaquin River water quality. CALFED has supported the continuation of a demonstration project to improve management of water quality on the main stem of the San Joaquin River. This project includes the improvement and upgrading of a system of flow, electrical conductivity and temperature sensors along the main stem of the San Joaquin River, along each of the major east-side tributaries and major west-side conveyances (Mud Slough, Salt Slough and in the San Luis Drain).

The newly installed monitoring stations and currently available computer simulation models of precipitation, snowmelt and runoff for the east-side watersheds allow for advance forecasts of east-side tributary streamflow. However, the same capability is not yet available for the west-side. West -side ephemeral streams can deliver flows up to 10 % of the total flow into the San Joaquin River, carrying significant sediment, salt, and selenium loads. Implementing new predictive modeling and measurement applications to the west-side drainage will expand the San Joaquin water quality monitoring network.

We propose to add to the existing real-time water quality management network by moving upstream into the Panoche/Silver Creek watershed whose ephemeral streams periodically deliver significant flow and contaminants to the San Joaquin River. We will accomplish this by: (1) developing a linked precipitation and streamflow forecast system; (2) install new telemetered precipitation, flow and water quality monitoring stations within the upper watershed; and (3) in conjunction with the Panoche/Silver Creek Coordinated Research Management Program (CRMP) and McCulley, Frick and Gilman, Inc (MFG), collect data during significant storm events and further develop an erosion and sediment transport model for the watershed.

This project will build upon and strengthen the existing water quality monitoring activities in the San Joaquin River and generate a larger more effective user base. By advancing our present monitoring capability with numerical weather and streamflow predictions, we will be able to forecast times of potential high runoff concentrations, maintain an expanded operational flow and water quality monitoring network, and provide advisories via the SJRMP web site and SJRWQOP listserver.

PROJECT DESCRIPTION

Real-time forecasting of contaminant loading from the Panoche/Silver Creek Watershed to the San Joaquin River

Proposed Scope of Work

Water quality in the San Joaquin River is affected by runoff and sediment contaminant loads from west-side ephemeral streams. Measures to limit these contaminant loads including early-warning systems of significant runoff events can help to reduce the impact on San Joaquin River water quality. CALFED has supported the continuation of a demonstration project to improve management of water quality on the main stem of the San Joaquin River. This project includes the improvement and upgrading of a system of flow, electrical conductivity and temperature sensors along the main stem of the San Joaquin River, along each of the major east-side tributaries and major west-side conveyances (Mud Slough, Salt Slough and in the San Luis Drain).

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This project will build upon and strengthen the existing water quality monitoring activities in the San Joaquin River (Fig. 1) and generate a larger more effective user base. Figure 1 shows the synergy of the proposed project with the CALFED-sponsored Real-Time Water Quality Management Project on the San Joaquin River and with other proposed actions to control salt loads from wetlands in the Grasslands Basin. By advancing our present monitoring capability with numerical weather and streamflow predictions, we will be able to forecast times of potential high runoff concentrations, maintain an expanded operational flow and water quality monitoring network, and provide advisories via the SJRMP web site and SJRWQOP listserver. The following sub-sections provide descriptions to our proposed modeling, monitoring, and sediment transport activities.

1. Modeling

1.1 Numerical Weather and Streamflow Prediction

The LBNL Regional Climate System Model (RCSM) is composed of a pre- and post-processor nesting a suite of physically-based models for predicting and assessing both climate and weather (Fig. 2). It has been successfully predicting fine-scale precipitation, temperature, energy budgets, soil moisture, runoff, and streamflow in California (Fig. 3) for over five years (Miller and Kim 1996, 1997, Kim et al. 1998). Initial and lateral boundary conditions for our mesoscale (12 km) numerical

weather predictions are provided by the NOAA National Center for Environmental Prediction (NCEP) large-scale forecasts. RCSM produces daily 48-hour forecasts with 6-hour archiving for all of California on a 12 km model grid and area-weighted basin-scale archived forecasts. Ongoing advances for improving the model precipitation forecasting capability include the testing of different precipitation convection schemes, simulation of a 1 km nonhydrostatic model for generating distribution functions, and experimental operational forecasts using the nonhydrostatic mesoscale model at fine scale (1 km).

1.2 *Coupled Runoff-Streamflow and Monitoring*

Accurate runoff forecasting in the Panoche/Silver Creek watershed is complicated by the aridity of the landscape and high dependence on the character of individual storm events. Not all storms generate runoff and streamflow in the ephemeral watercourses of the Panoche/Silver Creek watershed - sustained precipitation combined with high residual soil moisture can create conditions that generate high volumes of runoff. Flood producing rainstorms can occur over the Panoche/Silver Creek watershed anytime between October and April. The steep terrain and sparse vegetation cover, made worse by overgrazing, contribute to the "flashy" nature of floods from rainstorms of moderate intensity. The upper reaches of Panoche and Silver Creeks are well defined. Upon entering the Valley floor, the historic channel is ill defined and is truncated in many areas by cultivated fields, delivery canals and drains. During high runoff events, flood waters overtop streambanks on the valley floor and spread overland. In all cases the flooding occurs in a tract north of Belmont Avenue and ponds against the Third Lift Canal of the Firebaugh Canal Water District. Floods have occurred along Panoche Creek in 1950, 1952, 1962, 1973, 1977, 1978, 1981, 1986, 1994 and 1995.

Coupling output from the RCSM-streamflow to the monitoring system will be automated within the RCSM postprocessor. A script file will be written for a procedure that automatically transfers 6-hour cumulative precipitation and mean streamflow to the local computer used as the monitoring link. This will involve identifying the Panoche/Silver Creek watershed within the mesoscale model grid and archiving area-weighted basin averaged weather variables and fluxes. This will also require calibrating and verifying the RCSM-streamflow code with available historical rain gage and stream gage data. A number of soil moisture sensors buried in proximity to the precipitation and flow monitoring stations will help provide lead time information of the likelihood of storm-produced overland runoff. RCSM-produced soil moisture will be evaluated against observed values and used to improve model soil moisture predictability.

2. *Expanded Monitoring Network*

We propose to expand the existing real-time monitoring network, established by the San Joaquin River Management Program's Water Quality Subcommittee (SJRMP-WQS) by (1) installing two new telemetered precipitation stations in the upper watershed; and (2) installing flow and water quality monitoring stations at strategic locations along Panoche and Silver Creeks, above the confluence of these ephemeral streams. Lawrence Berkeley National Laboratory (LBNL) and McCulley, Frick and Gilman (MFG) will be responsible for installation and initial operation of these stations. The Coordinated Resource Management Program (CRMP) will assist in the training of local landowners to maintain these stations.

Figures 4 and 5 show the location of existing CIMIS weather stations (PNH, IDR and PCH) in the watershed and the approximate location of the new stations, respectively. Figure 4 is a USGS-based 1:125,000 USGS DEM with our GIS-derived streamflow network indicating the project footprint and proposed raingage and flow gage locations. Figure 5 was obtained from the California Data Exchange Center (CDEC) web site. CDEC provides users with 15 minute updated streamflow and precipitation gage data. Of these stations only PNH and PCH are currently operational. Stations PNH and PCH are inadequate to estimate precipitation totals when weather systems approach from the south or

south-west and hence are not sufficient for accurate runoff forecasting from the watershed. The location of the new precipitation stations will address some of this deficiency.

The flow and water quality station on Silver Creek will be located at a bridge culvert to minimize rating shifts and site maintenance. Only during the most severe storms does water flow over and around this bridge. The flow and water quality station on Panoche Creek has yet to be selected. Site accessibility, proximity of local landowners, the stability of the channel cross-section, and the catchment area will be considered in the final selection by LBNL and MFG.

These stations will be linked to the current CALFED-sponsored real-time water quality monitoring stations, and will be worked into the forecasting model used to predict San Joaquin River flow and electrical conductivity at Vernalis. Because the stations in the upper watershed will be inaccessible for much of the winter rainfall period, the sensors deployed at these stations will be robust and capable of producing accurate results with infrequent maintenance.

The soil moisture sensors will utilize state-of-the-art tomography technology developed at LBNL. These sensors are more robust and accurate than resistance blocks or tensiometers and draw little power. Collaborating surface water hydrologists at UC Berkeley (Dietrich et al. 1982,1992, 1993, 1998) have extensive experience in instrumenting hillslope sites with these sensors.

Additional sub-watersheds have been identified for instrumentation in order to calculate specific runoff and contaminant loading factors. Maintenance of existing collector stations with the installation of continuous flow and conductivity monitors to augment existing data will be required. Data on the ratio of water to sediment is needed to determine selenium and salt loads and will be collected by MFG as part of their sediment and erosion monitoring work. Chemical and isotopic data on water and sediment as well as data on the relationship between selenium speciation and particle size will be collected by MFG and LBNL to determine if readily obtained particle size analysis can be used to substitute for more costly selenium analysis. The facilities of the internationally recognized Center for Isotope Geochemistry at LBNL will be utilized for this component of the project. With knowledge of the underlying structure and geologic formations of the watershed isotopic data can be utilized to determine possible recharge pathways through historic streams channels, and remnants of natural alluvial fan structures to predict flow and movement of seleniferous waters.

3. Erosion and Sediment Transport

In the past decade the USGS established watershed collecting stations, designed to sample suspended sediment automatically on fast - rising streams since this area is remote and difficult to reach at appropriate times to sample in the rainy season. The water/sediment data was used to define primary mass loading of selenium into existing surface water systems, aquifers, and the adjacent alluvial fan in the western San Joaquin Valley. Samples taken from five initial sites in Panoche and Silver Creeks showed significant selenium transport in the initial first flush. Sustainability of a rather high level of selenium even with large amounts of water flowing down the creek, and a resurgence of higher selenium levels later in the storm sequence due to groundwater contribution to streamflow. Rain gauges and rain samplers were installed at nine locations in order to distinguish the runoff component from the groundwater component mainly through the use of the isotopic signatures of deuterium/hydrogen and oxygen(13)/oxygen.

Runoff, streamflow, and sediment transport will be modeled using TOPMODEL (Beven and Kirby 1979, Duan and Miller 1997) concepts. TOPMODEL is a physically-based semi-distributed hydrologic model that has been used extensively in Europe and the United States to predict rainfall runoff and sediment transport in both small and large watersheds (Kirkby 1997, Wolock et al. 1997). TOPMODEL computes surface overland runoff, shallow subsurface flow, and headwater channel

flow to the stream gauge station. The RCSM version of TOPMODEL uses similarity of a topographic index derived from Geographic Information System (e.g. ARC-INFO) coverages of basin topography to solve for lateral transport. Other required coverages include vegetation, soil type, and depth to bedrock. Application of the RCSM-TOPMODEL will utilize the recent project team data collection and reconnaisance activities within the watershed. The hydrologic model calibration will be initially based on the available gauge data and re-calibrated as each additional year of gauge data becomes available.

Simulation of sediment delivery to streams and its routing through stream systems will take place during the second year phase of this project. The primary data collection effort relative to the erosion and sediment modeling will be undertaken by MFG with assistance from members of the CRMP and LBNL. MFG have performed extensive survey work in the upper watershed in the past two years to determine the major sources of sediment export from the watershed and to map areas of erosion hazard (Fig. 6 and 7). LBNL's major role will be to apply a generalized, channel-network based, sediment routing model for the transport of coarse and fine sediment through the Panoche/Silver Creek stream system (Miller et al. 1998). The sediment transport model development is part of the Regional Climate Center-RESAC tasks and will link to the TOPMODEL hydrologic modeling of Miller and Kim (1996). This advanced routing model will account for storage effects on transit and residence times of sediment (Dietrich et al. 1982) and provide an assessment capability for determining the cumulative effects and recovery times after improved management practices. MFG will provide input to LBNL for the calibration and verification of the rainfall-runoff-erosion forecasting tools.

Summary

The proposed work strengthens existing watershed projects (CALFED Real-Time Water Quality Management Project on the San Joaquin River, USBR Riparian Corridor Evaluation Project, State Water Resources Control Board Erosion and Sedimentation Study of the Upper Panoche/Silver Creek Watershed, and the NASA Regional Earth Science Applications Center at Berkeley) with new proposed research applications at Panoche/Silver Creek. This cost-efficient approach will create a framework for advancing a basin-wide flow and water quality forecasting system.

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Location and Geographic Boundaries of the Project

The Panoche / Silver Creek watershed is located in Fresno and San Benito counties on the western edge of the San Joaquin Valley in the Coastal Range. The 300 square mile watershed contains a wide range of land uses: approximately 30% of the watershed west of Interstate 5 is utilized for livestock grazing on land managed by the Bureau of Land Management; the remaining land is in private ownership and is used as rangeland grazing or for agricultural crop production. Annual precipitation in the watershed is between 6 and 10 inches per year and the two emphemeral streams that provide drainage to the watershed, Panoche and Silver Creeks, only occasionally produce runoff. Under conditions of sustained precipitation of high intensity the watershed is prone to flash flooding. These flood events can produce significant sediment yields delivering large mass loadings of salts and trace elements such as selenium to the lower watershed.

ECOLOGICAL/BIOLOGICAL BENEFITS

Ecological/Biological Objectives

Contaminants entering the lower SJR are the primary stressors. Project benefits include: (1) generation of real-time discharge and conductivity data and estimates of selenium loading to address deficiencies in the current CALFED-sponsored real-time water quality forecasting project on the mainstem of the San Joaquin River, (2) modeling of runoff and sediment discharge to lower watershed, (3) coordination of water quality forecasting, and (4) the potential for increasing the frequency of meeting SJR water quality objectives for salinity as it enters the Delta.

By extension, this Program has the potential of reducing the number and/or magnitude of high quality releases made specifically for meeting SJR water quality objectives (e.g., releases of Stanislaus River flows from New Melones to lower the concentrations of dissolved solids in the SJR near Vernalis). The water thus saved can then be used to increase streamflows during critical periods for anadromous fish restoration efforts. Besides chinook salmon and steelhead trout, species and species groups benefitting from increased SJR streamflow include delta smelt, longfin smelt, splittail, white and green sturgeon, striped bass, marine/estuarine fishes, large invertebrates, and Bay-Delta aquatic foodweb organisms.

The project will install key real-time network stations with telemetered flow and conductivity in the Panoche/Silver Creek watershed. Conductivity data may be employed in development and monitoring adaptive management strategies that deal with use of the lower SJR by splittail, a species that can be impacted by high salinity at certain periods during its lifecycle. The project will enhance existing water quality programs that monitor aquatic contaminants (e.g., selenium and agricultural chemicals) that may cause acute toxicity and mortality or long-term toxicity and associated detrimental physiological responses. The discharge into the SJR of agricultural drainage high in selenium is a serious contaminant problem in the lower SJR basin and Bay-Delta. Selenium has caused reproductive failure in sensitive fish species and developmental deformities in waterfowl and shorebirds because of its ability to bioaccumulate within food chains in plant and animal tissue to levels that can be toxic to higher trophic organisms.

The project's water quality monitoring and modeling activities will increase the understanding of activities that affect SJR water quality. This information provided by this secondary benefit can be used to assess the impact of other management practices that attempt to reduce the pollutant load into the lower SJR and Bay-Delta. Species and species groups benefitting from reductions in contaminants entering the Bay-Delta are delta smelt, longfin smelt, splittail, white and green sturgeon, striped bass, resident fish species, marine/estuarine fishes and large invertebrates, Bay-Delta aquatic foodweb organisms, and waterfowl.

Non-ecological CALFED objectives addressed by project include improving SJR and Bay-Delta water quality for agricultural, drinking water, industrial, and recreational beneficial uses. The project will provide data that will facilitate the control and timing of wetland and agricultural drainage to coincide with periods when dilution flow is sufficient to achieve CALFED water quality concentrations.

TECHNICAL FEASIBILITY AND TIMING

The technology required for implementation of weather and streamflow forecasting at the Panoche/Silver Creek watershed is at LBNL. The LBNL Regional Climate Center has been successfully predicting fine-scale (12 km) precipitation, temperature, energy budgets, soil moisture, runoff, and streamflow in California for over five years (Miller and Kim 1996, 1997, Miller et al. 1997; Kim et al. 1999). The RCC's Regional Climate System Model (RCSM) consists of a pre-processor, process models and a post-processor (Fig. 1). The pre-processor is used to prepare input data from land surface geographical information (Miller 1997), satellite, and other remotely-sensed data. It has physically-based process models for atmospheric (MAS: Kim and Soong 1996), land-surface (SPS: Kim and Ek 1995), and hydrologic (TOPMODEL: Beven et al. 1995; Duan and Miller 1997) modeling and deep groundwater, forest-agriculture production (Amthor 1994, Tsuji et al. 1994), and river sediment transport (Dietrich et al. 1982, Brenda and Dunne 1997) models under development. The post-processor provides output data analysis, impact assessments, and visualization for a range of users. The NOAA National Weather Service - Sacramento Office and California-Nevada River Forecast Center have been using the RCSM predictions to augment their weather and stream flow forecasts, watches, and warnings. The success of this work has led to the establishment of the LBNL Regional Climate Center. This new Center is an umbrella organization to foster collaborative research in California. The new Center has partial support from NASA/RESAC ("California Water Resources Research and Applications Center") and DOE/LDRD ("Effects of 2xCO2 climate forcing on western U.S. hydroclimate using the High Performance version of the Regional Climate System Model"). The goals of the Center are to provide California users with state-of-the-art research, applications, and services related to water resources.

The majority of the work covered in this proposal is directed at delineating the Panoche/Silver Creek watershed, calibrating/verifying the hydrologic streamflow model, applying a to-be-developed sediment transport model, and expanding the present monitoring network. Streamflow model calibration will be based on available gage data at the I-5 bridge and at new stations to be located within Panoche and Silver Creeks upstream of their confluence.

The NEPA/CEQA documentation does not apply to the proposed work, as neither the gaging station installations or proposed model simulations will have any environmental impact.

Timing of this proposed project should coincide with the current Real-Time Water Quality Management project on the San Joaquin River. Critical times for operation of this system are during the winter and spring months when significant sustained precipitation events can initiate high rainfall-runoff events and cause flooding in the lower watershed.

MONITORING AND DATA COLLECTION METHODOLOGY

Biological/Ecological Objectives

The forecasting system described in this proposal will have direct benefits to the accuracy of water quality forecasts in the San Joaquin River and hence are coherent with CALFED biological and ecological objectives for the San Joaquin Basin.

Monitoring Parameters and Data Collection Approach

1. Satellite weather forecast data from NWS
2. Weather data from station at highway I-5 and Panoche Road;
3. Flow at three stations (Silver Creek above the confluence, Panoche Creek above the confluence, and Panoche Creek at entrance to lower watershed. (Panoche Creek at the I-5 bridge has been a USBR sponsored site since 1998 and is part of the Grassland Bypass Project monitoring program);
4. Remote water/sediment samplers placed in creek beds and flood plains to calculate loading factors for geologically delineated sub-watersheds;
5. Grab samples of unchannelized flood plain waters as flood progresses to Mendota Pool and the San Joaquin River. Integrate water quality sampling with current USGS water quality sampling program as part of the Grassland Bypass Program.
6. Sediment samples of flood plain and receiving canals such as the Mendota Pool and Firebaugh delivery canals to obtain estimates of sediment selenium loading. Integrate the data collection program with USGS and USBR sediment sampling program in the lower watershed as part of the Grassland Bypass Project.

Data Evaluation Approach

Real-time forecasts of flow and water quality parameters such as salt and selenium will be compared with gauged and monitored data in order to assess the accuracy of the forecasts and to improve calibration of model parameters in the rainfall-runoff watershed model. A quality assurance plan will be developed for all chemical analyses performed as part of this project as a check on laboratory accuracy and consistency with USGS and USBR chemical analyses.

Hypothesis/Question to be Evaluated	Monitoring Parameters and Data Collection Approach	Data Evaluation Approach	Comments/Data Priority
Task 1. Can runoff and streamflow be accurately forecasted with given available and collected data?	Rainfall and streamflow	Measured and simulated precipitation and streamflow will be compared	A good spatial distribution of observation stations and a sufficient time series is required
Task 2. What degree of accuracy and reliability can be expected from new rainfall, runoff and water quality monitoring sites?	Rainfall, streamflow, dissolved selenium, sediment-bound selenium	Mass balance using upstream and downstream measurements and site quality assurance measurements.	Remote stations will rely on land owner participation for maintenance and occasional troubleshooting.
Task 3. Can we predict erosion and sediment transport with a level of accuracy sufficient for watershed planning?	Suspended sediment, stream profiles, streambank reconnaissance	Compare erosion and sediment transport predictions with field measurements.	Physically based deterministic modeling approach with TOPMODEL should provide more accurate forecasts.

LOCAL INVOLVEMENT

Local involvement in the proposed project is significant and will occur directly through the actions of the Coordinated Resource Management Program (CRMP) and indirectly through the Grassland Bypass Project. Ms Nettie Drake and Mr Morris (Red) Martin of the CRMP are cooperators on the proposed study. Likewise Mr Chris Eacock from the US Bureau of Reclamation, who also serves on the Data Reporting Team of the Grassland Bypass Project, is a collaborator on the project.

The CRMP was formed in 1989 and comprises ranchers and landowners in the Panoche/Silver Creek watershed, local water conservation district personnel, agency personnel from State and Federal resource agencies, representatives from the City of Mendota and engineering consultants. In 1995, the CRMP was awarded an EPA 205j grant to perform an erosion and sedimentation study and to identify the major sources of sediment and sediment selenium discharged to the lower watershed during large storm events. This basic reconnaissance work was successful in creating a series of useful GIS maps and in identifying streambank erosion as a major contributor to sediment load during large flood events. The study also recognized the acute need for improved monitoring of rainfall and flows within the watershed.

Since the publication of the report the CRMP has revitalized interest in the Panoche-Silver Creek watershed, aided in part by the three years of hydrologically wet years and the dramatic winter flooding events in the El Nino year of 1998. Much of this revitalization of interest can be associated with the appointment of Ms Nettie Drake as the full-time coordinator of the CRMP for the past 3 1/2 years. Ms Drake has been active completing on-the-ground erosion and sediment control projects in the upper watershed. She is developing clinics through California State University, Fresno and helping to secure funding for the US Bureau of Reclamation and the Bureau of Land Management for the installation of a flow gauging station on Panoche Creek at the I-5 bridge. Ms Drake's role in the proposed project will be to develop landowner involvement in the maintenance of newly installed monitoring stations in the upper watershed.

The Grassland Bypass Project (GBP) is a multi-year experimental program to help control selenium discharge to the San Joaquin River from agricultural water districts within the 100,000 acre Grassland watershed. Flood flows from the Panoche/Silver Creek watershed introduce hundreds of pounds of dissolved selenium and tons of sediment-bound selenium to the lower watershed, adding to and complicating the accounting of selenium drainage in the GBP. The Panoche Water District, which is the lead local agency, involved in the GBP, has endorsed the project proposal because of the promise of improved accounting for selenium discharges from Panoche/Silver Creek during storm events and for the capability of producing runoff forecasts. With accurate runoff forecasts the Panoche Water District and other affected water districts will have time to alert their growers of potential flooding and will have time to make arrangements with the Grassland Water District for conveyance of these flood flows through the wetland channels that they operate.

Additional letters of endorsement are attached to this proposal.

Lawrence Berkeley National Laboratory
Real-time Forecasting of Contaminant Loading from the Panoche/Silver Creek Watershed to the San Joaquin River
(Principal Investigator – N. Miller)

Table 3 – Total Budget							
Task	Direct Labor Hours	Direct Salary and Benefits	Service Contracts	Materials and Acquisition Costs (inc. subcontract)	Miscellaneous and other Direct Costs	Overhead and Indirect Costs	Total Cost
Task 1	1348	111,872	0	1,094	11,600	58,018	182,584
Task 2	1348	76,405	0	127,230	11,500	49,054	264,189
Task 3	350	43,458	0	97,326	11,500	29,321	181,605
		0	0	0	0	0	0
		0	0	0	0	0	0
Totals	3045	231,735	0	225,650	34,600	136,393	628,378

Lawrence Berkeley National Laboratory
Real-time Forecasting of Contaminant Loading from the Panoche/Silver Creek Watershed to the San Joaquin River
(Principal Investigator – N. Miller)

Table 4 – Quarterly Budget									
Task	Quarterly Budget Oct – Dec 99	Quarterly Budget Jan – Mar 00	Quarterly Budget Apr – Jun 00	Quarterly Budget Jul – Sep 00	Quarterly Budget Oct – Dec 00	Quarterly Budget Jan – Mar01	Quarterly Budget Apr – Jun 01	Quarterly Budget Jul – Sep 00	Total Budget
Task 1	20,833	22,823	22,823	22,823	22,823	22,823	22,823	24,813	182,584
Task 2	6,800	13,600	48,000	68,045	33,024	35,850	23,785	35,085	264,189
Task 3	3,500	10,600	30,673	20,800	17,337	17,895	40,300	40,500	181,605
									0
									0
									0
Totals	31,133	47,023	101,496	111,668	73,184	76,568	86,908	100,398	628,378

Attachment E

BUDGET INFORMATION Non-Construction Programs						
SECTION A - BUDGET SUMMARY						
Grant Program Function or Activity (a)	Catalog of Federal Domestic Assistance Number (b)	Estimated Unobligated Funds		New or Revised Budget		
		Federal ©	Non-Federal (d)	Federal (e)	Non-Federal (f)	Total (g)
1.Water Quality		$628,378				$628,378
2.						$0
3.						$0
4.						$0
5.						$0
Totals		$ 628,378	$ -	$ -	S -	$ 628,378
SECTION B - BUDGET CATEGORIES						
6. Object Class Categories		GRANT PROGRAM FUNCTION OR ACTIVITY				
		(1)	(2)	(3)	(4)	Total (5)
a. Personnel		$ 151,985				$ 151,985
b. Fringe Benefits		$ 45,236				$ 45,236
c. Travel		$ 30,000				$ 30,000
d. Equipment		$ 100,000				$ 100,000
e. Supplies		$ 3,000				$ 3,000
f. Contractual		$ 108,000				$ 108,000
g. Construction		$ -				$ -
h. Other		$ 4,600				$ 4,600
i. Total Direct Charges (sum of 6a-6h)		$ 442,821				$ 442,821
j. Indirect Charges		S 185,557				$ 185,557
k. TOTALS (sum of 6i and 6j)		S 628,378	$ -	$ -	$ -	$ 628,378
7. Program Income						

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                                                                            Prescribed by CMB Circular

Attachment E

13. Federal	$ 291,320	$ 31,133	S 47,023	$ 101,496	$ 111,668
14. Non-Federal	$ -				
15. TOTAL (sum of lines 13 and 14)	$ 291,320	$ 31,133	S 47,023	S 101,496	$ 111,668

(a) Grant Program		FUTURE FUNDING PERIODS (Years)			
		(b) first	© Second	(d) Third	(e) Fourth
16. Water Quality		$ 179,652	$ 296,520	$ 187,306	
17.					
18.					
19.					
20. TOTAL (sum of lines 16-19)		$ 179,652	$ 296,520	$ 187,306	$ -

21. Direct Charges	Organizational Burden 17.5%	22. Indirect Charges	Provisional
23. Remarks	Calculated on labor and fringe benefits costs		

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TASKS:

1. Modeling-hydrologic calibration/verification for the Panoche/Silver Creek watershed (LBNL)
1.1. Measure available rain gauge and stream gauge data.
1.2. Perform model integration and continue to improve the hydrologic model calibration, verification and analysis.

2. Expanded Monitoring Network – install two rain gauge and two flow gage stations
2.1. Select optimal flow and rainfall gauging sites after watershed reconnaissance. (MFG, CRMP, LBNL)
2.2. Install automatic rain gauges and telemetry stations at selected sites (evaluate potential for rehabilitating station at Iridria (IDR) - (LBNL, MFG)
2.3. Install flow monitoring stations at selected sites - determine appropriate sensor technologies to employ. (LBNL, MFG)
2.4. Develop data quality assurance plan and work with CRMP and local landowners to obtain local participation and involvement in monitoring site maintenance. (LBNL, CRMP)

3. Erosion and Sediment Transport - Water quality sampling, tracer studies, and erosion studies.
3.1. Develop a monitoring plan and a quality assurance plan in conjunction with USGS, USBR and BLM to coordinate activities and avoid duplication of effort. Allocate resources to ensure that all major runoff events will be covered for water. (LBNL, MFG, CRMP, USGS, USBR)
3.2. Quality and sediment sampling: Sample significant runoff events - collect sediment and water samples for rising and falling limbs of storm hydrograph for Se analysis. (MFG, LBNL)
3.3. Use isotopic analysis of water and sediment samples to estimate partitioning coefficients between dissolved and solid Se phases. (MFG, LBNL)
3.4. Calibrate sediment erosion model using flow records and sediment turbidity data obtained from individual storm events. (MFG, LBNL)

COST-SHARING

The proposed project will benefit directly from the LBNL Regional Climate Center. Within the Center, is a California Water Resources Research and Applications Project funded by the NASA/RESAC Program. Activities at the Center include simulated hydroclimate products at short-term (2-3 day), seasonal, and long-term (downscaled $2xCO_2$ scenarios) time scales. The Regional Climate Center directly supports approximately $60,000/year of research and applications associated with precipitation forecasts over the Panoche/Silver Creek watershed at fine-scale.

The USBR provides funding to the USGS to maintain a flow monitoring station at the I-5 bridge at Panoche Creek. The cost of this monitoring this station and monitoring water quality during episodic storm events is $75,000/year

Local landowners that we anticipate maintaining these sites will provide approximately the equivalent of S25,000/year to maintain the monitoring sites.

Annual Cost Sharing:

LBNL	$60,000
USBR	$75,000
Local Partipation	$25,000

APPLICANT QUALIFICATIONS

NORMAN L. MILLER, Ph.D. is the Head of the Berkeley National Laboratory – Regional Climate Center. His primary interests are global and regional climate and weather processes, numerical code development, and sensitivity analyses for atmospheric, hydrological and biophysiological phenomena at a range of temporal and spatial scales. Miller has degrees in Engineering Science (Civil and Environmental) and Meteorology (Ph.D. 1987). Miller has been a DOE National Laboratory Scientist for over 10 years and has worked in the University of Wisconsin-Madison Water Chemistry Program for 3 years. He is currently the Principal Investigator for the NASA Regional Earth Science Applications Center: 'California Water Resources Research and Applications Center' (11/1998-present); Principal Investigator on a NASA Mission to Planet Earth Project, 'Global Climatic Impact on Regional Hydro-Climate and its Effect on Southeastern Asian Agro-Ecosystems' (10/96-Present); Partner Chief Investigator on the Australian Research Council International Project, 'Impact of Seasonal Variability on Hydrological Processes at Regional and Catchment Scales' (10/97-present); Co-PI on the DOE Project, 'Sensitivity of Southwestern U.S. Hydroclimate to 2xCO2 Climate Forcing' (10/98-present); Co-PI on the U.S. National Assessment – California Region. In the context of this Project, Miller brings precipitation and streamflow modeling expertise. His current collaboration with Prof. Dietrich (UC-Berkeley Geology and Geophysics Dept) is focusing on erosion and sediment transport research and applications.

NIGEL QUINN, Ph.D. P.E. received a BSc (Hons) in irrigation engineering and hydrology from the Cranfield Institute of Technology in England and spent the early part of his career as an irrigation engineer for Tate and Lyle Inc. designing and troubleshooting irrigation systems in England and in Africa. He left England for Iowa in 1978 where he taught agricultural water management, rural water supply engineering and surveying courses for three years, earning an MS in Agricultural and Civil Engineering and conducting research in soil erosion under crop canopy. In 1981 he took a position at Cornell University where he worked on various projects ranging from earthworm vermicomposting, pesticide model development and water supply and sanitation policy in developing countries, co-taught classes in surveying and computer programming and earned a PhD in civil and environmental engineering in 1987. He then joined the San Joaquin Valley Drainage Program, retaining a faculty affiliation with Cornell, and took responsibility for development of groundwater and drainage models to support the Drainage Program's planning effort. With the sunset of the Drainage Program he has continued his work with the US Bureau of Reclamation dividing his time between monitoring efforts in support of the Grasslands Bypass project, development of real-time forecasting tools for the San Joaquin River and selenium fate and transport research projects. He has been affiliated with Lawrence Berkeley National Laboratory for the past 8 years. Nigel is the author of over 50 publications and reports on various aspects of water resources and drainage engineering.

MORRIS (Red) MARTIN is the Manager of the Westside Resource Conservation District. He is a certified Professional in Erosion and Sediment Control from the Soil and Water Conservation Society and the International Erosion Control Association. Martin worked at the Soil Conservation Service for 32 years and retired as the Area Conservationist for the San Joaquin and Eastern California. He has been the Manager of the WRCD for 9 years and has administered 11 state and federal grants. Martin brings extensive historical knowledge of the Panoche/Silver Creek watershed and San Joaquin Valley to this Project.

FRED CHARLES, PE, Ph.D. was the lead investigator and overall project manager for the Panoche/Silver Creek Watershed Assessment (1998) and is intimately familiar with the watershed. He has over nine years of professional experience in environmental consulting related to upland, riparian, and wetland vegetation establishment and habitat restoration; sediment control BMP evaluation and design; hydrology; stormwater hydraulics and control; and soil quality assessment. Dr. Charles has developed and successfully implemented plans for site remediation, sediment control, and establishment of vegetation in disturbed areas. He has also conducted watershed assessments.

Dr. Charles proficiently models hydrologic, hydraulic, and non-point source processes through the use of existing models or by developing computer code to simulate specific unique situations. He is a registered professional engineer (civil) in California, Colorado, and Idaho. Dr. Charles is an affiliate faculty member at Colorado State University.

BRENAN ANNETT has considerable experience with biological monitoring and habitat characterization in wetlands, streams, rivers, lakes, and estuaries. He has worked on projectst throughout the United States for university research groups and state natural resource management agencies. He has experience assessing habitat usage by fish and invertebrates, and has been involved in evaluation of the effectiveness of dam bypass systems for fish. His work has included assessing stream reaches for habitat suitability as well as preparing and conducting salmonid spawning surveys in coastal watersheds. He has experience working with coordinated multiple stakeholder watershed planning programs, including the Oregon Coastal Salmon Restoration Initiative. He contributed to the evaluation of sedimentation and best management practices (BMPs) for erosion control in the Panoche/Silver Creek Watershed Assessment (1998). He has assisted with ecological risk assessment in wetland and terrestrial environments. He is currently assessing environmental information related to the Natural Resource Damage Assessment (NRDA) claims in the Coeur d' Alene River Basin in northern Idaho. His responsibilities there include evaluating habitat relationships among aquatic species in that watershed. Mr. Annett regularly participates in the Panoche/Silver Creek CRMP and Westside Resource Conservation District meetings.

NETTIE R. DRAKE, has been the full time coordinator for the Panoche/Silver Creek CRMP for the past three and half years. During this time, the CRMP has completed a set of by-laws, goals for a Plan of Work, obtained a 205(j) grant for a sedimentation study completed in November 1998 and four grants for the continuous support of a full time coordinator. Drake completed on the ground projects with landowners for erosion and sediment control programs. She developed three Clinic projects through the California State University, Fresno, School of Agricultural Sciences and Technology, funded for the construction and operation for the last two years of a gaging station on Panoche Creek at the Interstate 5 bridge. She also established a positive public image and support from local, state and federal agencies and legislators.

CHRIS M. EACOCK is a Soil Scientist/Natural Resources Specialist with the US Bureau of Reclamation in Fresno. Chris has extensive experience with developing environmental documentation and has worked on a variety of projects in the Grasslands Basin including Panoche/Silver Creek for more than a decade. Chris is a member of the Data Reporting Team of the Grassland Bypass Project and has assisted in the installation of remote telemetry stations for flow and EC monitoring. He also serves as the US Bureau of Reclamation representative on the CALFED- sponsored Real-Time Water Quality Management project on the San Joaquin River.
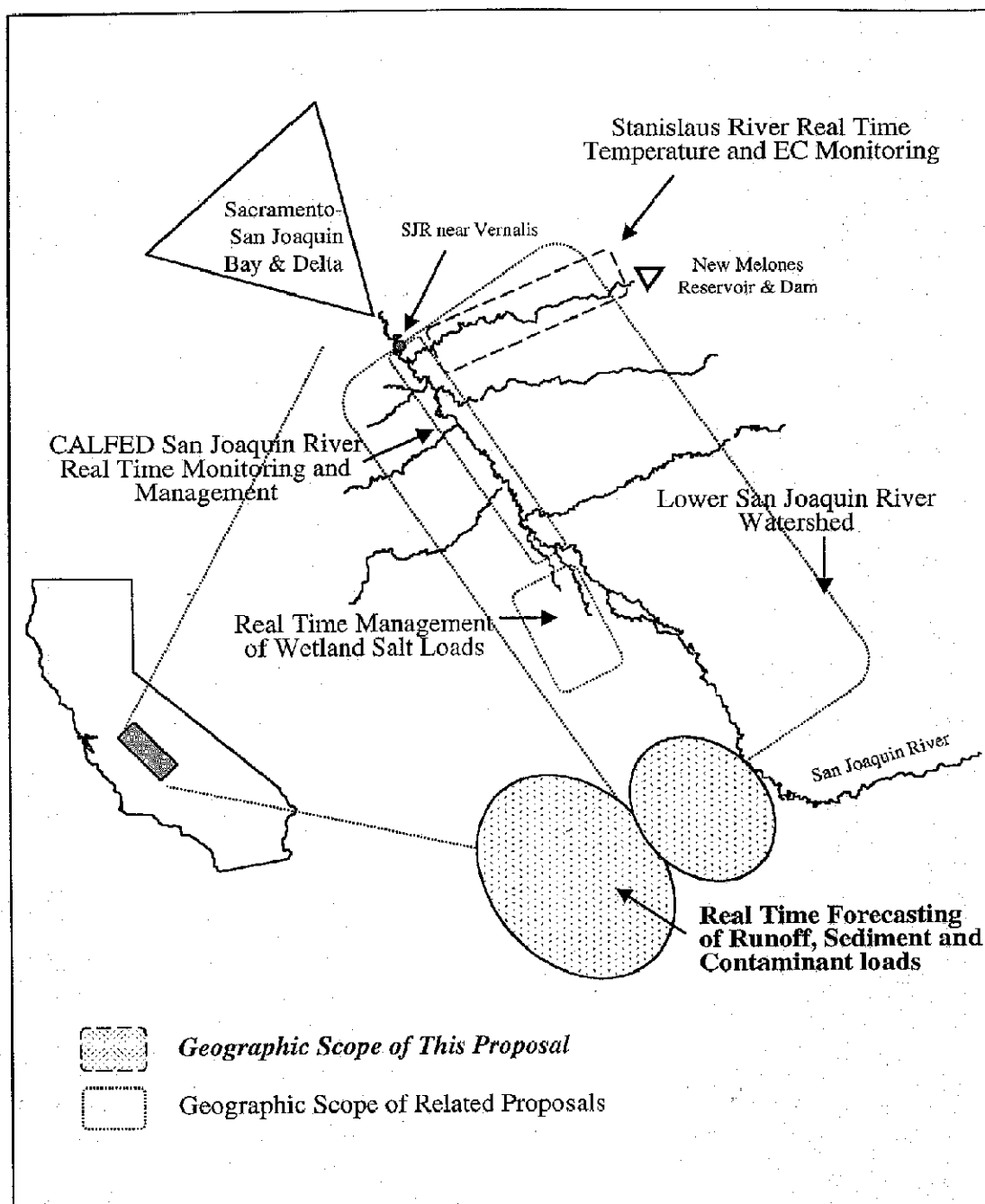
Figure 1. Geographic Scope of Related CALFED Project Proposals
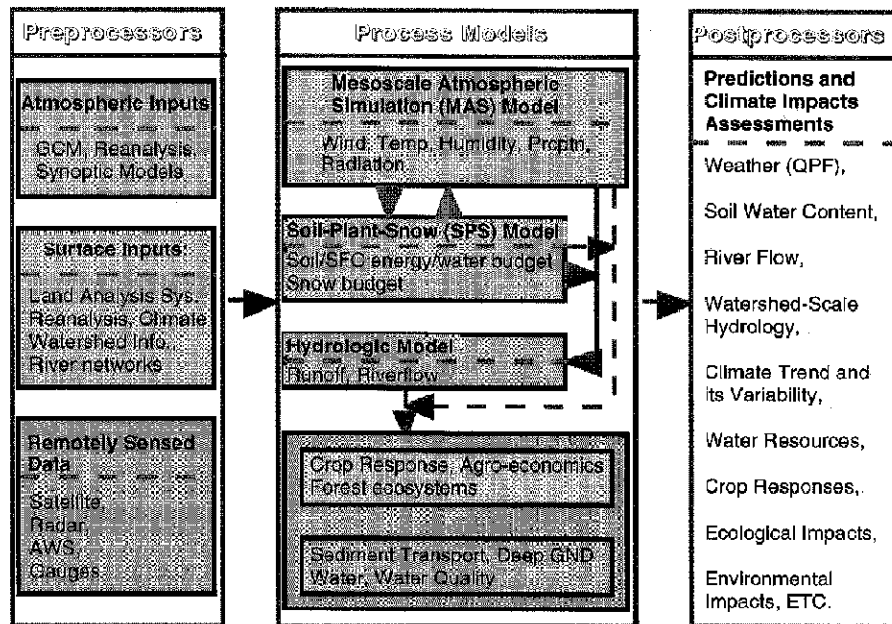
THE REGIONAL CLIMATE SYSTEM MODEL

Preprocessors	Process Models	Postprocessors
Atmospheric Inputs GCM, Reanalysis, Synoptic Models	**Mesoscale Atmospheric Simulation (MAS) Model** Wind, Temp, Humidity, Precptn, Radiation	**Predictions and Climate Impacts Assessments** Weather (QPF),
Surface Inputs: Land Analysis Sys. Reanalysis, Climate Watershed Info, River networks	**Soil-Plant-Snow (SPS) Model** Soil/SFC energy/water budget Snow budget **Hydrologic Model** Runoff, Riverflow	Soil Water Content, River Flow, Watershed-Scale Hydrology, Climate Trend and its Variability,
Remotely Sensed Data Satellite, Radar, AWS, Gauges	**Crop Response, Agro-economics Forest ecosystems** **Sediment Transport, Deep GND Water, Water Quality**	Water Resources, Crop Responses, Ecological Impacts, Environmental Impacts, ETC.

Fig. 2. The RCSM consists of a pre- and post-processors nesting a suite of process models. The pre-processor prepares input data from land surface geographical information, satellite, and other remotely-sensed data. Process models include physically-based atmospheric, land-surface, and hydrologic models and developing codes for deep groundwater, forest-agriculture production, and river sediment transport.

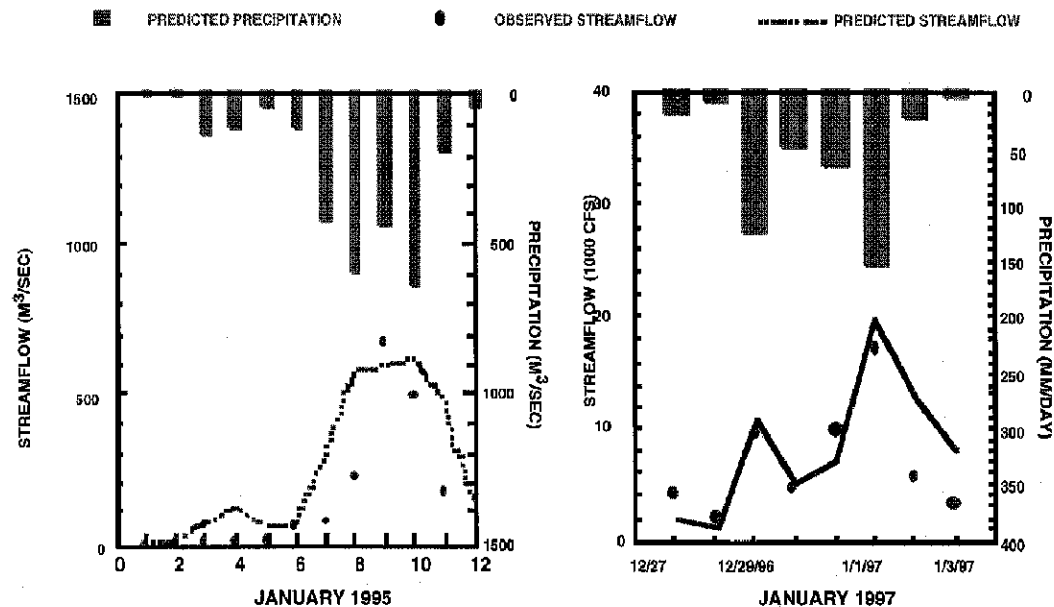# Quantitative Precipitation and Streamflow Forecasts (Hopland, Russian R.)

Fig. 3 The RCSM has successfully predicted 48-hour precipitation and streamflow flood stage (magnitude and timing) at the Hopland Gauge along the California coastal Russian River.

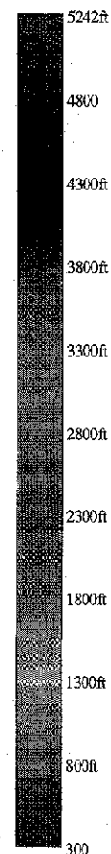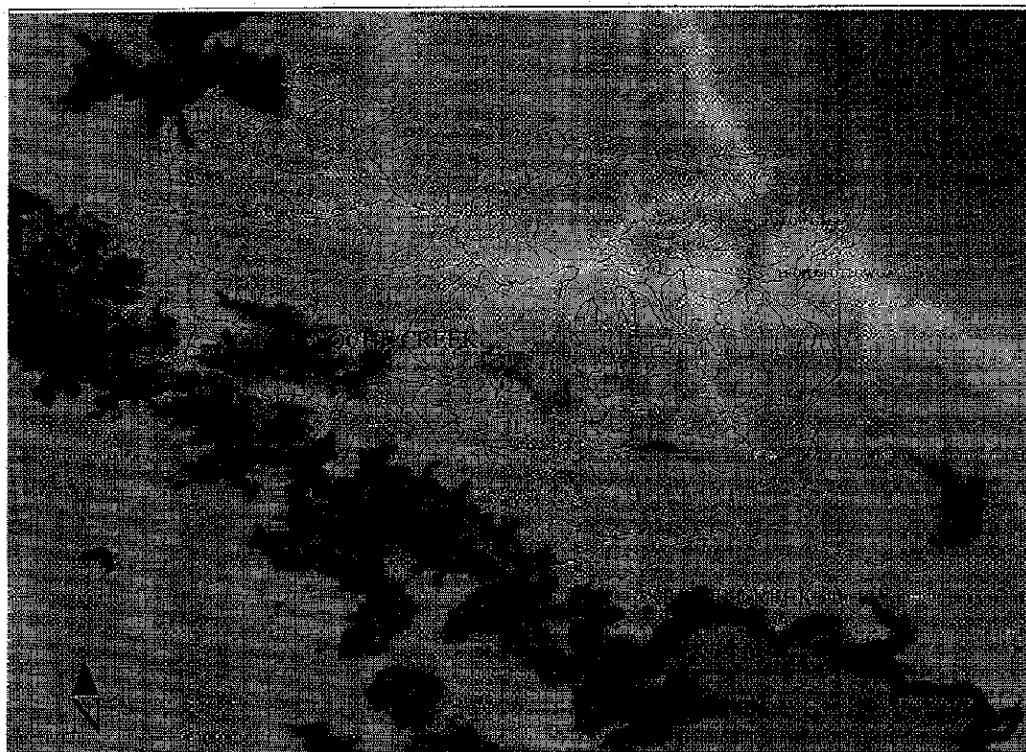# The Panoche/Silver Creek Watershed
(USGS 1:125000 DEM)

Fig. 4 Project Footprint and Steam Network Based on the USGS Digital Elevation Model (DEM) Data.

California Department of Water Resources   Division of Flood Mana

| Current River Conditions | Snowpack Status | River Stages/Flows | Reservoir Data/Reports | Satellite Images | Station |
| Data Query Tools | Precipitation/Snow | River/Tide Forecasts | Water Supply | Weather Forecasts | Text |

Stations around PANOCHE ROAD

(please wait while querying map server)
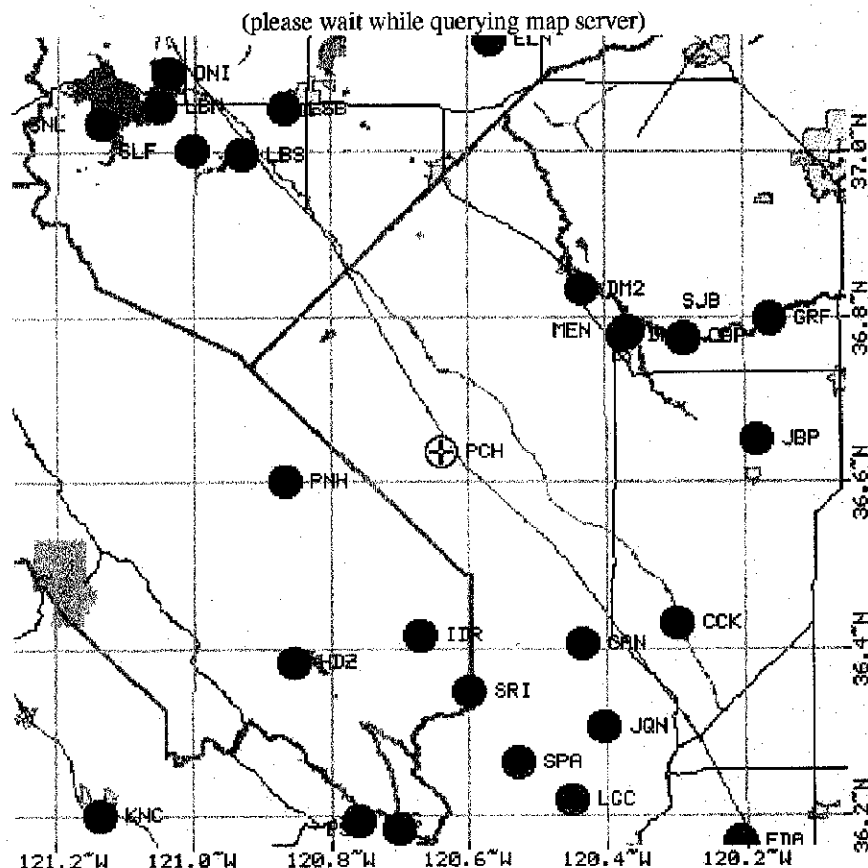
Zoom in |Zoom out
Only stations within 30 minutes of latitude or longitude of the center of the map are shown.
Map generated by the US Census Bureau map service. Check out their Map Browser interface.

Stations near here: ASS BM2 BAR MCK BDC BRA BAW BUC BNR BUR CAH CCK CAN CRN CMT
CVR ONI DM2 DM3 CHW CHT CBP CLN CTK CYC CRS DSN EDA ELN EST MIL FRT FGC GAL
GGR GRF HND HTG HDZ HID HLS IDR JBP JQN KTM KTT KNC AMW CSW MCS MCR ATN LTB
LRA LDC LSB LBN LBS LGC MDR MGN MAP MAR MRP MEN MFS MFF MRC MSN MST MMF
MCF MNG MTG NCM NCD EXC NEW OKH ORE OWN PNH PCH PKF PSV SJB SJP SJS SJF SLF
LUS SNL SRI SMI SPA SWW THP TID TLC WRT WST ZPC MBB

http://cdec.water.ca.gov/cgi-progs/
nearbymap?slald=PCH&zoom=1.

Fig. 5. California Data Exchange Center (CDEC) Raingage Stations about Project Footpr

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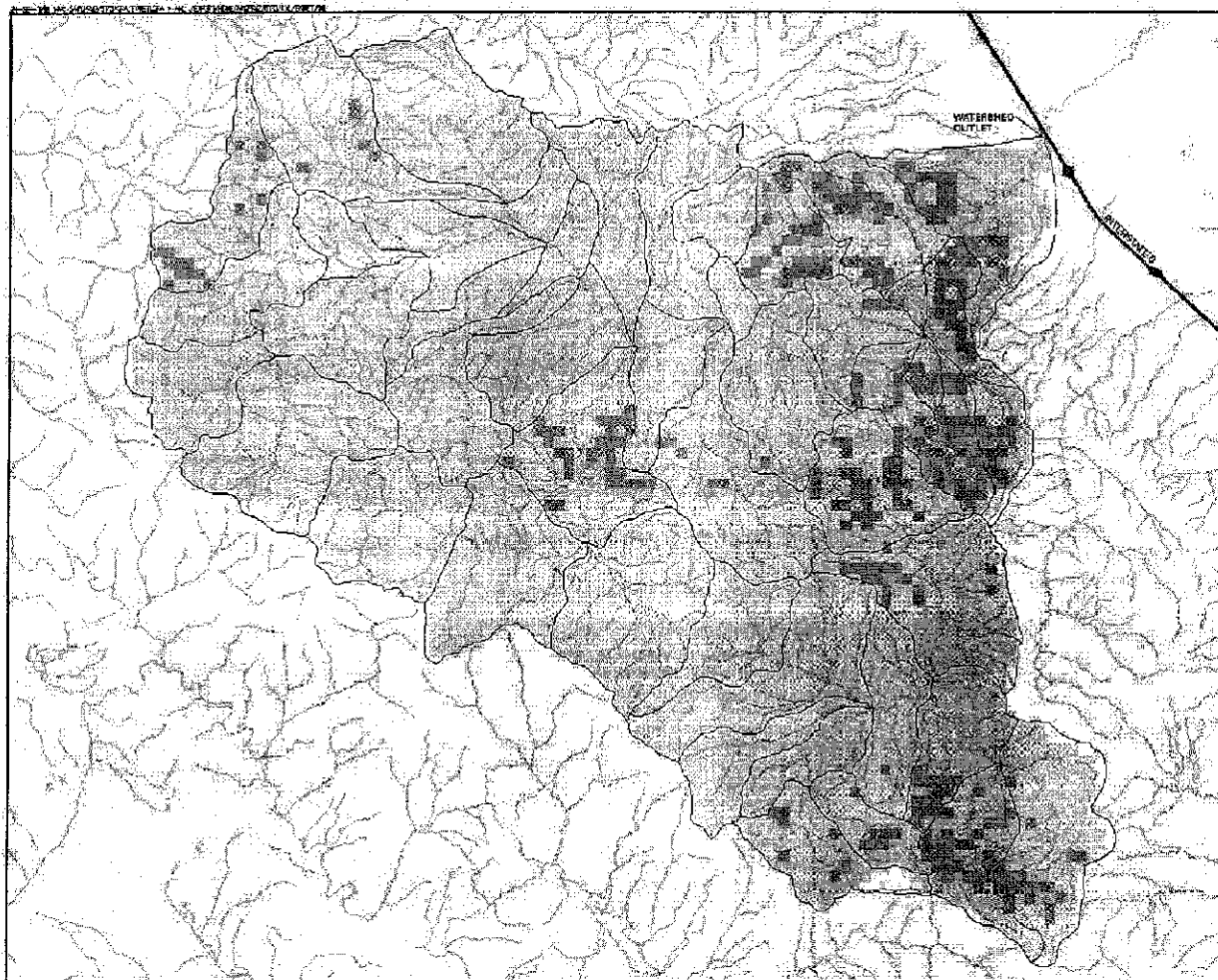
EXPLANATION

EROSION (TONS/ACRE)

0 TO 10

10 TO 20

20 TO 30

GREATER THAN 30

NOTES:

1. RESULTS ARE FOR EXISTING (SPRING 1993) WATERSHED CONDITION

2. PREDICTIONS BASED ON A 100-YEAR RUNOFF RATE AT WATERSHED OUTLET

SCALE IN FEET

0   12,000   24,000

PANOCHE/SILVER CREEK WATERSHED ASSESSMENT

FIGURE 8

EROSION HAZARD RATING MAP FOR EXISTING CONDITIONS

| PROJECT 617.5.4: | DATE: SEPTEMBER 24, 1993 |
| REV. 0 | BY: MCF | CHECKED: RC |

McCULLEY, FRICK & GILMAN, INC.

providing environmental consulting and engineering services

EXPLANATION

TOTAL SEDIMENT YIELD (TONS)

0 TO 1,000

1,000 TO 5,000

5,000 TO 10,000

10,000 TO 50,000

50,000 TO 75,000

GREATER THAN 75,000

NOTES:

1. RESULTS ARE FOR EXISTING (SPRING 1999) WATERSHED CONDITION

2. PREDICTIONS BASED ON A 100-YEAR RUNOFF RATE AT WATERSHED OUTLET

SCALE IN FEET

0   12,000   24,000

RANCHO/RIVER CREEK WATERSHED ASSESSMENT

FIGURE 7

TOTAL SEDIMENT YIELD (TONS) FOR EXISTING CONDITIONS

| PROJECT 8175.4.1 | DATE: SEPTEMBER 24, 1999 | |
| REV. 0 | BY: NCP | CHECKED: R.D. |

McCULLEY, FRICK & GILMAN, INC.
providing environmental consulting and engineering services
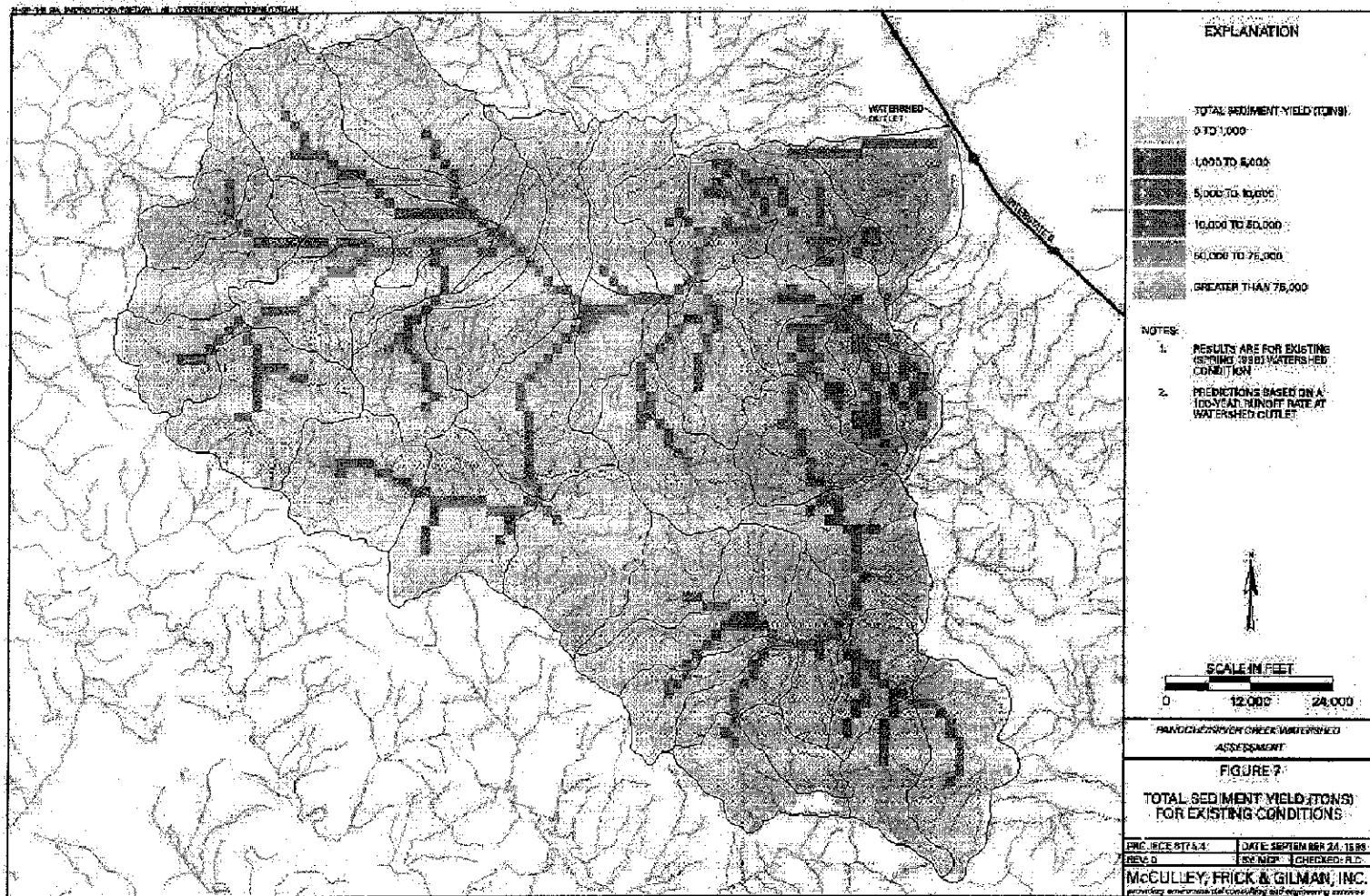
LETTER OF NOTIFICATION

Lawrence Berkeley Laboratory

1 Cyclotron Road   Berkeley, California 94720

(510) 486-4000

NIGEL W.,T. QUINN, PhD, P.E>
EARTH SCIENCES DIVISION
PHONE: (510) 486 7056 FAX: (510) 486 7152

March 30, 1999.

Ms. Lydia Beiswanger, Chief Deputy
Merced County Board of Supervisors
2222 M Street
Merced, CA 95340.

Dear Ms. Beiswanger:

This letter is to inform you of our intent to submit a proposal to the CALFED Bay-Delta Program entitled "Real-Time Forecasting of Contaminant Loading from the Panoche/Silver Creek Watershed to the San Joaquin River". This a joint proposal with the Panoche/Silver Creek Coordinated Resource Management Committee, a grass-roots organization comprising local landowners, State, Federal and local agency personnel.

Accurate forecasting of flood flows will provide an early warning to the Grassland Area Farmers allowing more time to plan emergency response plans to these flooding events. Flooding of farm land during 1997 and 1998 overwhelmed the resources of the agricultural water districts in the Grasslands Basin to contain these flows. The effect of these flood flows on water quality in the San Joaquin River has not been quantified adequately to assess the impact on River assimilative capacity for selenium, boron and TDS. The monitoring associated with this project will help to improve this deficiency and will help to improve the accuracy of water quality forecasts made by the currently supported CALFED Real-Time Water Quality Management project on the San Joaquin River.

We believe that successful completion of this study will be of great benefit to landowners and water district personnel in the Grassland watershed of Merced County.

Sincerely,

Nigel W.T. Quinn

Geological Scientist

PANOCHE WATER DISTRICT

April 7, 1999

Dr. Nigel W.T. Quinn
Lawrence Berkeley National Laboratory
1 Cyclotron Road, 70A-3317K
Berkeley, CA 94720

Subject: Panoche Water District Support for CALFED Grant Proposals

Dear Dr. Quinn:

The Panoche Water District has a long history of supporting innovative drainage reduction strategies on the west-side of the San Joaquin Valley. As a participant in the Grassland Bypass Project the water district has invested millions of dollars in the past 3 years to improve monitoring and increase control over subsurface tile drainage leaving the water district. Significant reductions in selenium loads contained in these discharges have been necessary to meet the strict selenium load limits imposed by the Project.

The CALFED proposal entitled "Real Time Forecasting of Contaminant Loading from the Panoche/Silver Creek Watershed to the San Joaquin River" that you are submitting cooperatively with the Panoche/Silver Creek Coordinated Resource Management is of great interest to the District. Rainfall-runoff from the Panoche/Silver Creek watershed caused flooding to farm land during 1997 and 1998 and overwhelmed the resources of the District to contain these flows. Accurate forecasting of flood flows will provide an early warning to the Grassland Area Farmers allowing more time to plan emergency response plans to these flooding events. Successful completion of this study will be of great benefit to landowners and water district personnel in the Grassland watershed.

Sincerely,

Dennis Falaschi
General Manager

I —018674

California Natural Resource Foundation

1151 Kadota Avenue, Atwater, California 95301
Phone: (209) 358-9026   Cellular: (209) 761-2563   Fax: (209) 726-8881   Email: mark@elite.net

Saturday, March 20, 1999

Mr. Earle Cummings, Chairman
Water Quality Subcommittee
San Joaquin River Management Program
Department of Water Resources
3251 S Street, Sacramento, CA 95816

Subject: CNRF Support for CalFed Grant Proposals

Dear Mr. Cummings:

The California Natural Resources Foundation is a charitable non-profit charitable Foundation and supports a broad array of projects to benefit the preservation of productive natural systems. Recent projects we have supported or facilitated include wetland restoration at the Castle Land and Cattle Co. and mitigation banks in the Merced area and the Suisun Marsh. We are working with interested parties in Merced and other San Joaquin Valley cities to use constructed wetlands to improve the quality of discharges from municipal wastewater treatment plants.

We support your Subcommittee's grant proposals to CalFed, and have commitments from our board members to assist in your proposal. Our board includes members with skills in finance, habitat development, community relations, State and Federal Contract Management, and regulatory compliance. We have a cooperative agreement in place with the California Waterfowl Association for projects that require engineering of water management structures. We are very interested in your proposals:

1. To develop understanding and improved management of water quality and wetlands in the Grasslands; and
2. The Panoche-Silver Creek Coordinated Resource Management effort to address sediment and trace elements reaching the San Joaquin River from west-side tributaries.

The CNRF appreciates the invitation to support these projects, and we are pleased to provide our endorsement for the grant proposals. If a grant is offered for these projects, we can offer our services to accept and disburse grant funds, provide technical assistance in habitat evaluation or development work and in community outreach. We are particularly interested in opportunities to involve First Nation's people in habitat work, and Board member Mike Hammar, through his position with the Rural Indian Health Services, has links and contacts to make that happen.

You can contact me at (209) 358-9026. We look forward to helping carry out these projects.

Sincerely,

Ronn T. Slay, President,
California Natural Resource Foundation

SUMMERS ENGINEERING, INC.

CONSULTING ENGINEERS

887 N. IRWIN ST. - P. O. BOX 1122
HANFORD, CALIFORNIA 93232

JOSEPH R. SUMMERS
JOSEPH C. McGAHAN
ROGER L. REYNOLDS
BRIAN J. SKAGGS
SCOTT L. JACOBSON

Note new
area code
→

TELEPHONE
(559) 582-WEST

TELECOPIER
(559) 582-7632

April 13, 1999

COPY

Dr. Nigel W.T. Quinn
LAWRENCE BERKELEY NATIONAL LABORATORY
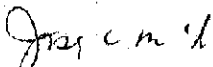1 Cyclotron Road, 70A-3317K
Berkeley, CA 94720

SUBJECT: Grassland Area Farmers Support for CALFED Grant Proposals

Dear Dr. Quinn:

The Grassland Area Farmers have a long history of supporting innovative drainage reduction strategies on the west side of the San Joaquin Valley. As the proponent of the Grassland Bypass Project, the Grassland Area Farmers have invested millions of dollars in the past 3 years to improve monitoring and increase control over subsurface tile drainage leaving the area. Significant reductions in selenium loads contained in these discharges have been necessary to meet the strict selenium load limits imposed by the Project.

The CALFED proposal entitled "Real-Time Forecasting of Contaminant Loading from the Panoche/Silver Creek Watershed to the San Joaquin River" that you are submitting cooperatively with the Panoche/Silver Creek Coordinated Resource Management is of great interest to Grassland Area Farmers. Rainfall-runoff from the Panoche/Silver Creek watershed caused flooding of farmland during 1997 and 1998 and overwhelmed the resources of the drainage area to contain these flows. Accurate forecasting of flood flows will provide an early warning to the Grassland Area Farmers allowing more time for emergency response plans to deal with these flooding events. Successful completion of this study will be of great benefit to the Grassland Area Farmers in the Grassland watershed.

Sincerely,

Joseph C. McGahan
Drainage Coordinator for the Grassland Area Farmers

JCM/p

I —018676

REAL-TIME MANAGEMENT OF WATER QUALITY IN THE
SAN JOAQUIN RIVER BASIN, CALIFORNIA

N. W. T. QUINN AND J. KARKOSKI

REAL-TIME MANAGEMENT OF WATER QUALITY IN THE SAN JOAQUIN RIVER BASIN, CALIFORNIA[1]

N. W. T. Quinn and J. Karkoski[2]

ABSTRACT: In the San Joaquin River Basin, California, a real-time water quality forecasting model was developed to help improve the management of saline agricultural and wetland drainage to meet water quality objectives. Predicted salt loads from the water quality forecasting model, SJRIODAY, were consistently within ± 11 percent of actual, within ± 14 percent for seven-day forecasts, and within ± 26 percent for 14-day forecasts for the 16-month trial period. When the 48 days dominated by rainfall/runoff events were eliminated from the data set, the error bar decreased to ± 9 percent for the model and ± 11 percent and ± 17 percent for the seven-day and 14-day forecasts, respectively. Constraints on the use of the model for salinity management on the San Joaquin River include the number of entities that control or influence water quality and the lack of a centralized authority to direct their activities. The lack of real-time monitoring sensors for other primary constituents of concern, such as selenium and boron, limits the application of the model to salinity at the present time. A case study describes wetland drainage releases scheduled to coincide with high river flows and significant river assimilative capacity for salt loads.
(KEY TERMS: water quality; real-time management; salts; drainage.)

INTRODUCTION

Real-time water quality management requires techniques that update the state of knowledge of a system continuously and allow actions to be taken to meet water quality objectives. Such techniques are being developed for the San Joaquin River Basin of California to promote voluntary compliance with state water quality objectives for priority pollutants such as selenium, boron, and total dissolved solids.

The techniques required to collect and transmit flow and stage data are well established. In California, public water agencies such as the Department of Water Resources (DWR), the U.S. Bureau of Reclamation (USBR) and the U.S. Geological Survey measure flow and stage routinely for a variety of applications. Only the California Data Exchange Center (CDEC), a department within the DWR, provides river stage and flood warning information on a real-time basis. The major clients of this system are local and state agencies concerned with flood management and the provision of emergency services. Agencies such as the US Army Corps of Engineers use this information to determine reservoir release schedules during high runoff periods. The real-time water quality management system under development for the San Joaquin River Basin takes advantage of some of the features of the existing hydrologic data acquisition and forecasting programs. Unique aspects of the real-time water quality management system that are not replicated by current programs are:

1. Use of water quality sensors: currently only EC, temperature, and pH are continuously logged, although a greater number of constituents of concern within California's river systems.

2. A continuous and integrated system of data error checking and validation because the data are used for regulatory purposes.

3. Addition of control systems that can be used to manage agricultural and wetland drainage water flow and water quality.

4. Institutions that coordinate actions and responses of regulators, operators, and other public and private entities.

BACKGROUND

The San Joaquin River drains a basin of approximately 34,560 square kilometers. Runoff from the basin is dominated by snowmelt and rainfall from the Sierra Nevada Range and its foothills to the east of the San Joaquin River. The three east-side tributaries, the Merced River, the Tuolumne River, and the Stanislaus River, provide the majority of the flow in the San Joaquin River (Figure 1). The predominant land use in the San Joaquin River Basin is irrigated agriculture. Irrigated agriculture on the west side of the Basin is supplied predominantly by imported water from the Sacramento-San Joaquin Delta, whereas the east-side tributaries and ground water provide the majority of the water supply to the east side of the Basin.

From a water quality point of view, the discharges from the Grasslands Basin are of particular interest.

The Grasslands Basin is a hydrologic unit situated west of the San Joaquin River, bounded by Westlands Water District to the south and State Highway 140 to the north, that naturally drains to the San Joaquin River. The soils in the Grasslands Basin are naturally high in salts and of low permeability. The low permeability combined with the importation of water has resulted in a shallow groundwater table. To maintain productivity, the installation of artificial drainage is necessary in low-lying agricultural areas. Drainage produced from a 41,000 hectare agricultural area in the southern part of the Grasslands Basin [hereafter referred to as the Drainage Study Area (DSA)] contains high concentrations of certain trace elements and soluble salts that are harmful to fish and wildlife. The primary constituents of concern are salt, boron, and selenium.

In addition to discharges from the DSA, surrounding wetland areas also contribute a significant salt
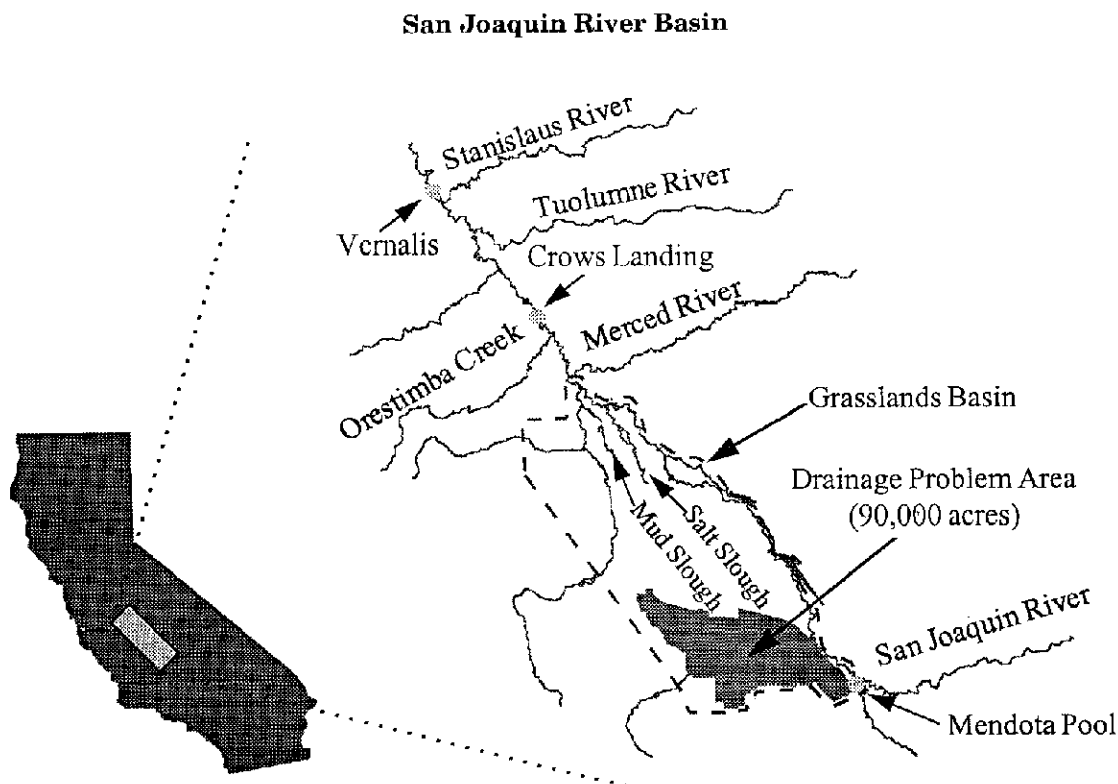
San Joaquin River Basin

Figure 1. The San Joaquin River Basin Showing the Outline of the Grasslands Basins and the 41,000 Hectare Drainage Problem Area (DSA).

load to the San Joaquin River during the spring months (Grober et al., 1995). The combined discharges from the agricultural lands and wetlands is conveyed through a system of canals and natural streams to the San Joaquin River. Figure 2 shows that the salt load contribution to the River from Mud and Salt Sloughs, which contain return flows from both agricultural and wetland areas in the Grasslands Basin, is high relative to other tributary sources of salt in the San Joaquin River Basin. Dilution of the poor quality discharges from the Grasslands Basin is provided by the east-side tributaries. Flows in the east-side tributaries are regulated to a large degree by upstream reservoirs which, in turn, are operated according to predetermined rules and release schedules. These rules and release schedules account for flood storage, fish migration, irrigation, hydropower, water quality control, and recreation.

In contrast to the high degree of regulation and control of east-side tributary flows, the discharge of pollutants from the DSA has historically been unregulated and uncontrolled. Sump pumps associated with subsurface agricultural drainage systems are designed to turn on automatically when water reaches a set level in the sump. Hence, the pattern of discharges from agricultural lands generally mirrors the irrigation season. In contrast, surface drainage discharge from seasonal wetlands occurs in early spring between February and April. Some control of the scheduling of the seasonal wetland drainage can be exercised by wetland managers, although these schedules are determined to a large extent by habitat requirements and local management preferences of privately owned duck clubs.

The timing of the discharges of dissolved solids and trace elements from the DSA and the timing of reservoir releases are such that the assimilative capacity of the San Joaquin River is often exceeded at the compliance monitoring locations. Opportunities have been identified for adjusting the timing of discharges and reservoir releases (A. Hildebrand, 1989, Letter sent to Ed Imhoff, Program Manager, San Joaquin Valley Drainage Program (1985-1990), Sacramento, California). The practical constraints to making such
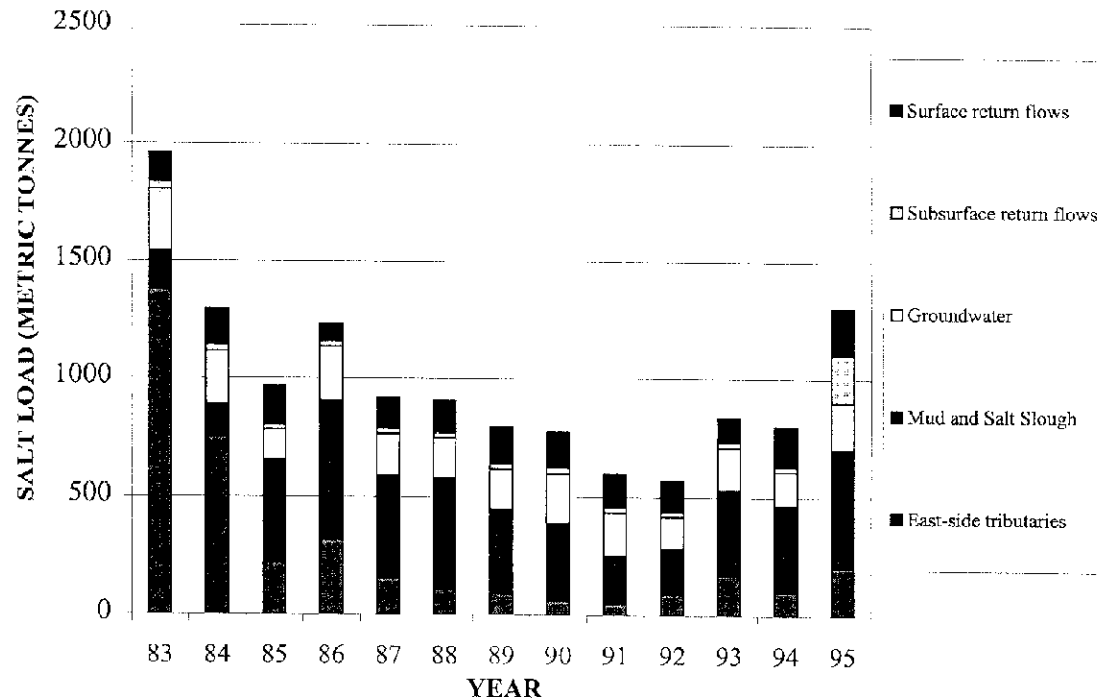

Figure 2. Salt Loading to the San Joaquin River From Various Sources.

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adjustments have not been thoroughly explored (Karkoski et al., 1995a). By making such adjustments, temporal variations in water quality can be minimized, and the frequency of violation of water quality objectives can be reduced. A real-time water quality management system, along with pollutant load reduction, could allow continued discharge of salt from agricultural lands and wetlands while minimizing the impacts on the San Joaquin River and eliminating violations of water quality objectives.

REAL-TIME WATER QUALITY MODELING IN THE GRASSLANDS BASIN

Previous real-time water quality modeling efforts in the Grasslands Basin have mostly focused on screening-level assessments of operational constraints on, and opportunities for, agricultural drainage discharges. The U.S. Bureau of Reclamation (USBR) developed a sophisticated planning model that considered several alternatives to meet selenium and boron water quality objectives in the San Joaquin River (Quinn, 1993; Quinn and Delamore, 1994). The alternatives considered were irrigation improvements, drainage water reuse, land retirement, and the use of holding reservoirs to regulate the release of drainage to the River. These alternatives were optimized to minimize the size of the regulating reservoirs and to ensure that the constraining water quality objective (selenium or boron) was not exceeded. The results of the modeling analysis suggested that with investments in drainage recycling facilities and the construction of regulating reservoirs with a total capacity of 4.3 million cubic meters, water quality objectives could be met at all times (USBR, 1991). The USBR model assumed perfect forecast and response to receiving water assimilative capacity and that the water quality of irrigation water and groundwater pumpage remained constant during the simulation period.

Another screening-level model developed by the Central Valley Regional Water Quality Control Board (CVRWQCB) (J. Karkoski, 1995 unpublished analysis) considered the effects of load reductions and model and response errors on the sizing of regulating reservoirs. Model and response errors were expressed by allowing only 80 percent of the available assimilative capacity to be used. When evaporation effects were considered, the storage size required for regulating reservoirs was found to be 26.8 million cubic meters. The large difference in regulating reservoir volume (4.3 vs. 26.8 million cubic meters) is a function of the different assumptions made in the two modeling approaches. In the case of the USBR model, the full assimilative capacity of the river was available and no annual selenium load cap was imposed; whereas the CRWQCB model assumed suboptimal use of the assimilative capacity and imposed the CRWQCB Basin Plan's annual selenium discharge load cap of 3,624 kg (CVRWQCB, 1996). The CRWQCB model also assumed that a mean annual discharge of selenium from the agricultural water districts to the San Joaquin river was 2,945 kg. Although the above models differed in certain assumptions, the premise shared by both models was that regulating reservoirs could be constructed and managed to respond to real-time conditions in the San Joaquin River.

In contrast, the analysis used by the CVRWCB in developing its control plan for selenium was based on a modified EPA load setting methodology (Karkoski et al., 1995b; CVRWQCB, 1994) which assumes extremely limited ability to forecast, and therefore respond to, available assimilative capacity. The monthly flow record (1970-1991) was divided into eight flow regimes which differed based on water year type (dry and wet) and season. The selenium effluent limits were set for the low flow conditions in each flow regime (quasi-steady state) to meet an "allowable" rate of violation – once every three years as allowed by federal regulation.

Table 1 compares the annual allowable selenium load from the CVRWQCB analysis for dry years and wet years, under dynamic (real-time) versus quasi-steady state modeling assumptions. It is clear from Table 1 that the advantages of using a real-time system are significant to the discharger allowing a greater selenium load to be discharged, annually, without violating selenium concentration objectives.

TABLE 1. Comparison of Real-Time and Quasi-Static Selenium Load Limits.

	Wet Year Se Load (kg)	Dry Year Se Load (kg)
Quasi-Static	1405	455
Dynamic (Real-Time)	3364	2105

Operations Models

Although the screening level models point to potential advantages of adopting a real-time water quality management system, the actual opportunities presented by such a system can only be evaluated with the development of an operations model. An

operations model is inherently more data-intensive than a screening or planning model.

The literature contains many examples of water related problems that have been addressed fully or in part through real-time data acquisition, information dissemination and operational control. Much of the literature describes the general field of optimization, dynamic programming, and optimal control theory. The efforts of these researchers highlight some of the challenges and potential solutions in the development of a real-time water quality management system for the San Joaquin River.

Krajewski et al. (1993) considered the real-time optimal control of power plant cooling water discharges. The effect of a single major discharge (power plant cooling water return flow) was simulated, along with ambient hydrometeorological conditions to determine compliance with the temperature standard 20 km downstream. A thermal model was used in conjunction with an optimization model; the optimization model minimized losses when the power plant was unable to generate power at a potential level and imposed penalties for violating the temperature standard. The loss function was stochastic in nature since it was dependent on the thermal model – the thermal model forecasted hydrometeorological conditions based on assumptions of initial and boundary conditions. Krajewski et al. (1993) were able to determine the effect of errors in forecasted hydrometeorological conditions on model error and the calculated net benefit.

Novotny et al. (1992) investigated the challenges of applying a real-time management and control system to wastewater treatment plants. Treatment plants are often designed based on assumptions of steady-state concentrations of influent to the treatment plant and effluent concentrations from the plant equal to allowable water quality standards. Novotny et al. (1992) suggested that a treatment process control and management scheme be adaptive, predictive, and efficient. Such a management model should be able to adapt to variations in input, able to forecast input changes, and be efficient by limiting idleness of plant units and the discharge of untreated waste. Storage was suggested by Novotny et al. (1992) as a buffer against temporal variations in assimilative capacity of the receiving water. Model features included an assessment of treatment plant output to the environment, response of the environment to the output and optimization of the system to maximize efficiency.

Krajewski et al. (1993) demonstrated that model errors due to lack of information on hydrodynamic parameters such as channel geometry, poorly understood processes such as ground water inflow, and lack of input data such as wetland and agricultural return flows can have a significant impact on the benefits

realized from a real-time water quality management system. Novotny et al. (1992) suggested that a recursive parameter estimation method for autoregressive moving average models or a neural network model would provide the desirable features of adaptability and predictability required for real-time control of wastewater treatment processes. The need for these features is heightened when the size and variability of the system to be modeled increases (i.e., when the forecast lead times and model errors increase).

Although the general problems of data reliability are common to most of the real-time applications discussed in the literature, most appeared relatively tractable compared to the water quality management problem in the San Joaquin River Basin.

REAL-TIME DATA ACQUISITION SYSTEM

Although river stage, EC and temperature have been monitored on a real-time basis, other real-time water quality monitoring is generally limited to those properties and constituents such as temperature, pH, or dissolved oxygen for which no sample preparation is required. Techniques for the real-time measurement of other parameters of interest in the San Joaquin River, such as selenium and boron, have not been established nor are reliable sensors available.

A real-time water quality monitoring network has been established in the Grasslands Basin and along the main stem of the San Joaquin River. Nine sites were chosen for real-time monitoring of flow, electrical conductivity and temperature along the San Joaquin River and its tributaries. These monitoring sites are listed in order from upstream to downstream, together with the sensor data collected at each site:

- San Joaquin River at Lander Avenue (EC, flow, temp)
- Salt Slough at Highway 165 Bridge (EC, flow, temp)
- Grasslands Bypass (compliance point – site B) (EC, flow, temp)
- Mud Slough near Gustine (EC, flow, temp)
- Merced River near Stevinson (EC, flow, temp)
- San Joaquin River at Newman (flow)
- Orestimba Creek (EC, flow)
- San Joaquin River at Crows Landing (EC, flow, temp)
- San Joaquin River at Vernalis (EC, flow, temp)

The locations of these stations are shown in Figure 3. The data from these stations is currently telemetered via modem to central data processing stations in the USBR and the DWR, where the information is
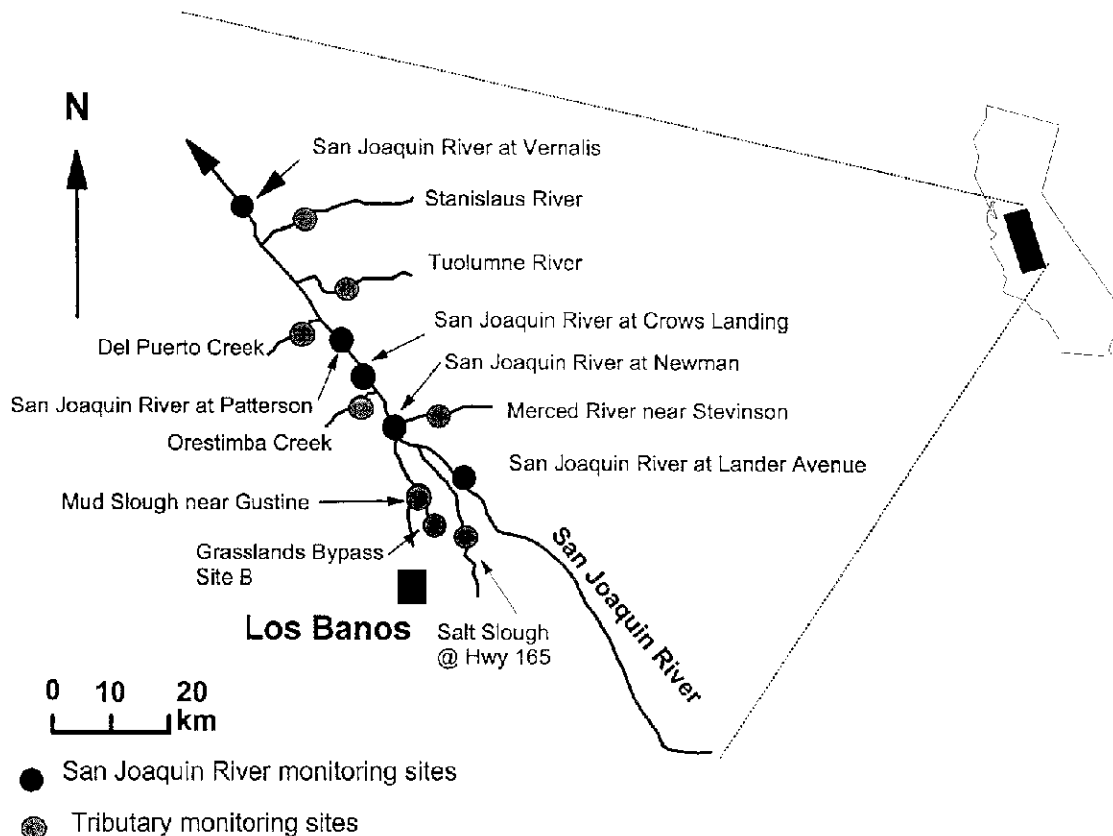
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Figure 3. Location of Real-Time Monitoring Sites in the San Joaquin River Basin.

checked for errors and missing values and parsed into a format accessible by a daily water quality forecasting model. The evolution of this model and its application is the nexus of water resources modeling activities in four agencies within California: the State Water Resources Control Board, the U.S. Bureau of Reclamation, the California Department of Water Resources, and the California Regional Water Quality Control Board (Kipps *et al.*, 1997).

SAN JOAQUIN RIVER DAILY INPUT-OUTPUT MODEL

The San Joaquin River Daily Input-Output (SJRIO) model is a mass balance model which calculates daily flows and concentrations of total dissolved solids (TDS), boron, and selenium for a 96 km reach of the San Joaquin River from Lander Avenue to Vernalis (SWRCB, 1985). An extensive database was assembled, with data for water years 1977 to 1985, to run the model. The SJRIO was modified to accept stochastic data, so that it could be run with historical data, stochastic data, or a combination of both. The model has been further modified to run on a daily time step so that it can be used with real-time flow and water quality data on the SJR.

The daily model, SJRIODAY, contains the following tributary river segments:

- 10 km of Salt Slough below the Highway 165 gaging station
- 15 km of Mud Slough below the Gustine gaging station

- 8 km of the Merced River below the Stevinson gaging station
- 24 km of the Tuolumne River below the Modesto gaging station
- 14 km of the Stanislaus River below the Ripon gaging station
- Several kilometers of three west-side tributaries: Del Puerto, Orestimba and Hospital/Ingram Creeks

Daily flow calculations for the SJRIODAY model are made using hydrologic routing techniques. Water quality constituents are considered conservative. Those data are used to establish initial conditions for model runs and to generate a two-week forecast of flow and EC. In the absence of real-time data, boron and selenium forecasts are made using the most recently available data combined with historical means and the best judgment of the modeler. Real-time or forecasted rainfall can be used to account for additional runoff in the basin. Real-time data are supplemented by mean monthly flow and water quality data for other model components for which no real-time data are available, including: groundwater, riparian and appropriative diversions, surface and subsurface agricultural return flows, riparian evapotranspiration, evaporation, and precipitation. These components are estimated within the model based on seasonal variability and wet/dry water year classification provided by the modeler.

GRAPHICAL USER INTERFACE

A Graphical User Interface (GUI) was designed for the SJRIODAY model to be user friendly by exploiting the point-and-click capability of the Windows system (Figure 4). Upon execution of the GUI a colorful map of the San Joaquin River system is displayed on the computer screen. The user can direct the arrow cursor to any part of the map and, using the point-and-click system available within Windows, recall the data for review or for changes of input conditions. The user can also scroll through a display of dates, viewing the temporal variations of water quality parameters at any map location on the screen and can display spatial color coded changes in water quality at any given time. By clicking at a time advance button, the user can create a near-animation of salt movement through the San Joaquin River between Lander Avenue and Vernalis.

The GUI performs five functions:

1. Retrieves real-time monitoring data for initial conditions by modem from a dedicated computer or web site. (Telemetered data updated weekly by field staff after quality assurance checks have been performed.)
2. Edits and uploads water operators' operational schedules.
3. Runs the predictive SJRIODAY model.
4. Downloads model results.
5. Displays the results.

There are two versions of the GUI. The general version for water operators can edit and upload operational schedules of reservoir releases, download the results of computer runs using the forecasting model, and display the output from these runs. This version does not allow the user to make a full model run. The full version of the GUI has the same capabilities as the operators' version but also allows the user to download monitoring data and to run the forecasting model, SJRIODAY.

MODEL RESULTS AND FORECASTS

Forecasts of flow and water quality at Vernalis were made each week from February 12, 1996, to June 30, 1997, and a post audit of forecast accuracy was broadcast on the electronic listserver, comparing the forecasts with observations obtained from CDEC and the real-time monitoring system (Kipps et al., 1997). Figures 5 and 6 show the performance of the forecasting model for predicting flow and EC at Vernalis. The observed CDEC and model-simulated flows at Vernalis and the observed CDEC and simulated TDS concentrations and assimilative capacities are in closer agreement in the case of the 1-week forecast than for the two-week forecast, as expected. The model performed well during most of 1996 and, in particular, the summer months, when flows and water quality on the San Joaquin River were dominated by agricultural drainage from Mud and Salt Sloughs. Predicted salt loads from the water quality forecasting model, SJRIODAY, were consistently within $\pm$ 11 percent of actual, within $\pm$ 14 percent for seven-day forecasts and within $\pm$ 26 percent for 14-day forecasts for the 16-month trial period. In general, the model tends to overestimate flow as well as EC.

The San Joaquin Valley was subjected to a series of severe winter storms between December 25, 1996,
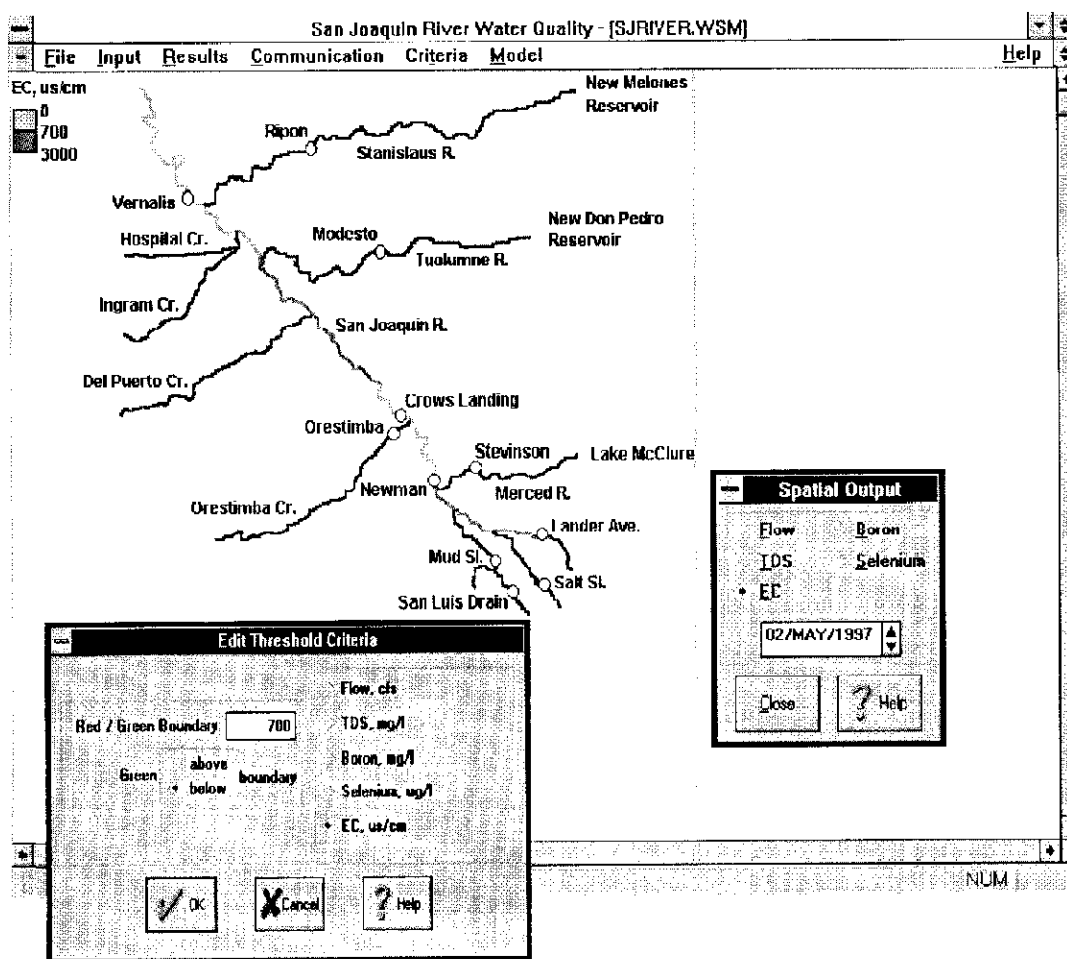
Figure 4. Graphical User Interface for the SJRIODAY Flow and EC Forecasting Model. The model can also access historical water quality data for selenium and boron. The EC criterion (entered as TDS) is user defined and produces a red coloration along the main stem of the San Joaquin when objectives are exceeded and a green coloration when water quality objectives are being met.

and January 25, 1997, which produced an extraordinary volume of runoff from the eastside Sierran watersheds. Without an accurate watershed model, runoff forecasts were based on estimates of the flood hydrograph from each contributing watershed and real-time flow data. When flow and EC for the 48 days dominated by rainfall/runoff events during the trial period were eliminated from the data set, the error bar decreased to ± 9 percent for the model, and ± 11 percent and ± 17 percent for the seven-day, and 14-day forecasts respectively. R-squared values for the

model, seven-day and 14-day forecasts were 0.93, 0.88, and 0.76 using the full data set, which improved to 0.95, 0.91, and 0.79 when the 48 days dominated by rainfall-runoff events were eliminated.

Figures 5 and 6 illustrate the problems encountered in making accurate flow forecasts during the trial period. Although the model and the runoff forecasts continued to overestimate real-time flows between January 14 and January 25, 1997, levee breaks along the San Joaquin River accounted for some of the discrepancy. In some instances, the model
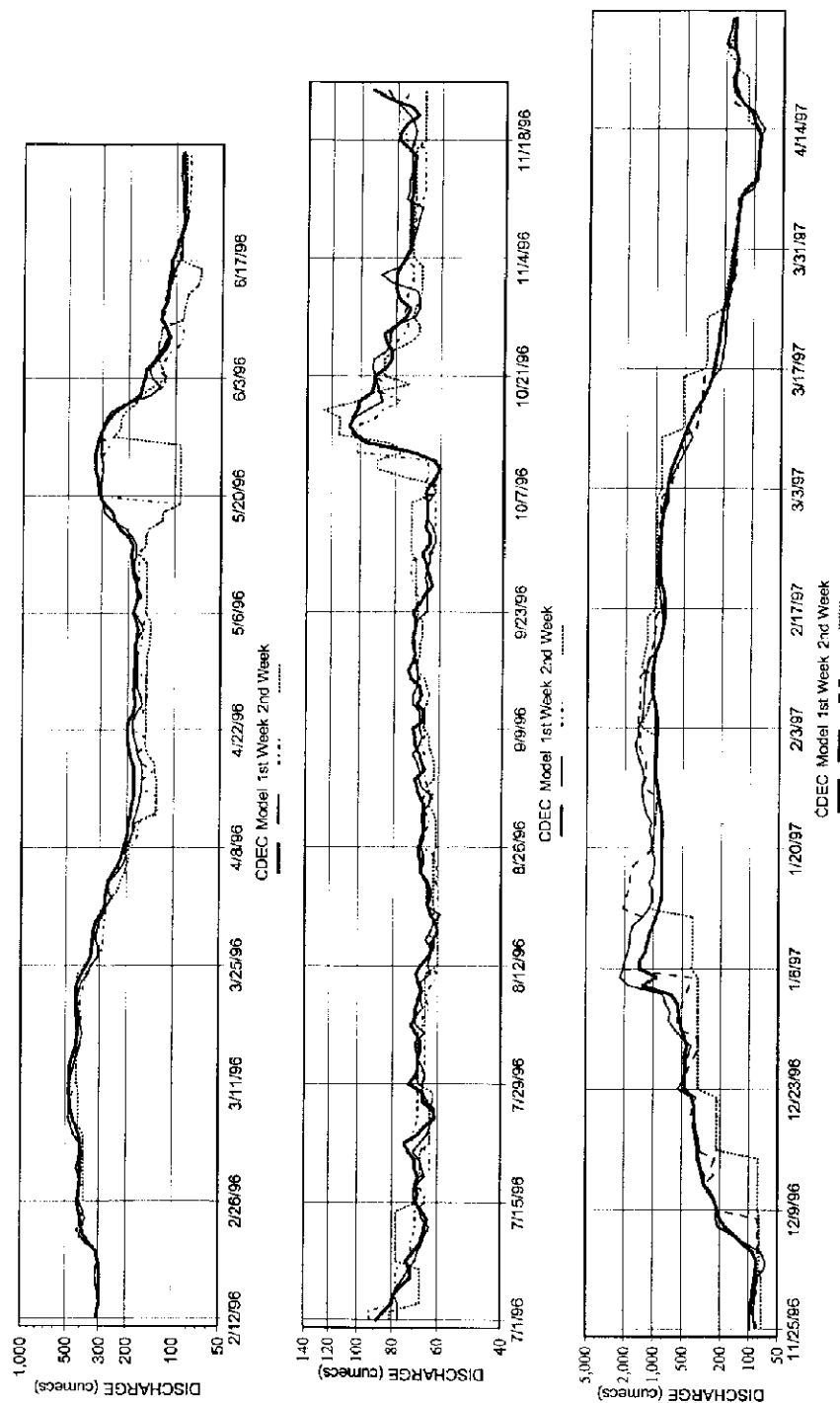
Figure 5. Comparison of Observed Vernalis Discharge Data from CDEC with Model Predictions and with One and Two Week Forecasts (February 1996 to April 1997).
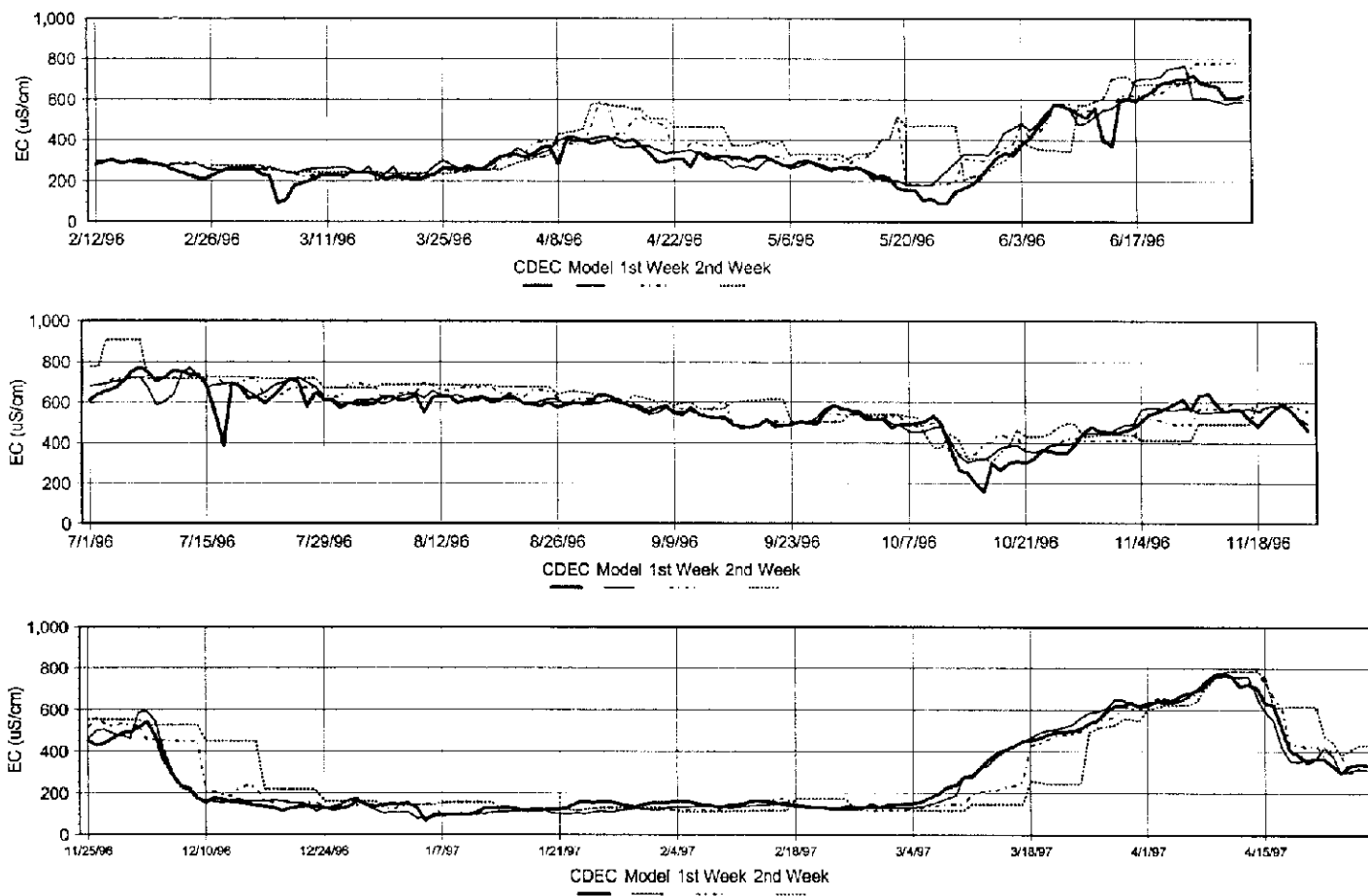
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Figure 6. Comparison of Observed Vernalis Electrical Conductivity (EC) Data from CDEC with Model Predictions and with One and Two Week Forecasts (February 1996 to April 1997).

and forecasts alerted the analysts to problems in the monitoring networks, which included the failure of an EC sensor and a flooding problem when a portion of the river flow was diverted around the gaging station. The dominance of east-side tributary flows on San Joaquin River water quality during the trial period improved the accuracy of prediction. Model and forecast EC concentrations were not significantly different from the real-time EC data.

REAL-TIME MANAGEMENT OF FLOW AND WATER QUALITY

The accuracy of the forecasts performed with the aid of the model is greatest when schedules of east-side reservoir releases and estimates of agricultural and wetland drainage discharges are available. These deterministic inputs reduce the errors associated with the inherently stochastic nature of river flows and agricultural loads. Reliable forecasts and the capability of dischargers and diverters to act upon these forecasts requires information exchange and coordinated management.

REOPERATION OF EAST-SIDE RESERVOIRS

Water districts make releases from east-side reservoirs for power generation, irrigation, and municipal water to cities and towns located along the major San Joaquin tributaries. Reservoir operators are obligated to make releases to aid fish migration during certain times of the year pursuant to their FERC licenses and for recreation and other purposes negotiated with local interests. East-side reservoir operators have had few incentives in the past to cooperate with agricultural water districts and wetland refuge managers to improve water quality conditions in the San Joaquin River. These attitudes are shifting with recent legislation to encourage water transfers and water marketing. Such incentives have allowed the Federal Government to acquire water supplies for tributary pulse flows to aid fish migration. The U.S. Bureau of Reclamation has developed a scheme to compensate east-side water districts for additional scheduled releases that exceed normal operations for the purpose of improving the salmon fishery. These pulse flows provide windows of opportunity for west-side agricultural water districts and wetland managers to increase discharge flows and salt loads without violating the San Joaquin River salinity objectives at Vernalis.

WETLAND DRAINAGE MANAGEMENT

Wetland discharges of salt to the river have come under increased scrutiny ever since the provision of additional Federal water supply under the Central Valley Improvement Act of 1992. In the Grasslands Basin there are 41,000 hectares of wetlands – a combination of permanent, seasonal and upland habitat for migrating wildfowl of the Pacific Flyway. The greatest impact to the San Joaquin River is from seasonal wetlands which are usually flooded in the months of September and October and drain during the spring months of March, April and May. Approximately 10 percent of the salt in the San Joaquin River derived from these wetland discharges. The potential for real-time management of salts from these wetlands is constrained by the necessity to provide maximum food value and habitat requirements for different wildfowl species.

During early January 1996 the Grassland Water District, in cooperation with the Water Quality Committee of the San Joaquin River Management Program (SJRMP), conducted an experimental early drainage release of ponded water. This early release provided a potential benefit to the River by reducing the likelihood of downstream salinity impacts later in the season and reducing the risk of salinity objective violations. The Water District requested that the authors provide a forecast of the most advantageous time to make this release. A model forecast, made on January 15, 1996, suggested that the combination of high river flows and an imminent rainstorm might provide the necessary assimilative capacity. The peak wetland release was timed so that it would coincide with peak flow in the San Joaquin River. Wetland flushing began on January 18 and ended on February 19, with the peak flow occurring between January 27 and February 10. This peak flow arrived at Vernalis between February 1 and February 14 (Figure 7). On January 15, before the arrival of the wetland releases, flow at Vernalis was approximately 56 cubic meters per second, and the EC was 1000 uS/cm. At the time of arrival of the peak wetland releases at Vernalis, flow at Vernalis ranged from 148 to 294 cubic meters per second and the EC ranged from 220 to 430 uS/cm. Excess assimilative capacity was observed in the River throughout the simulation period as a result of the rainfall-runoff events in the upper watershed. No violations of the EC objective occurred during the trial period, and there were no EC violations in the San Joaquin River during March and April 1996.
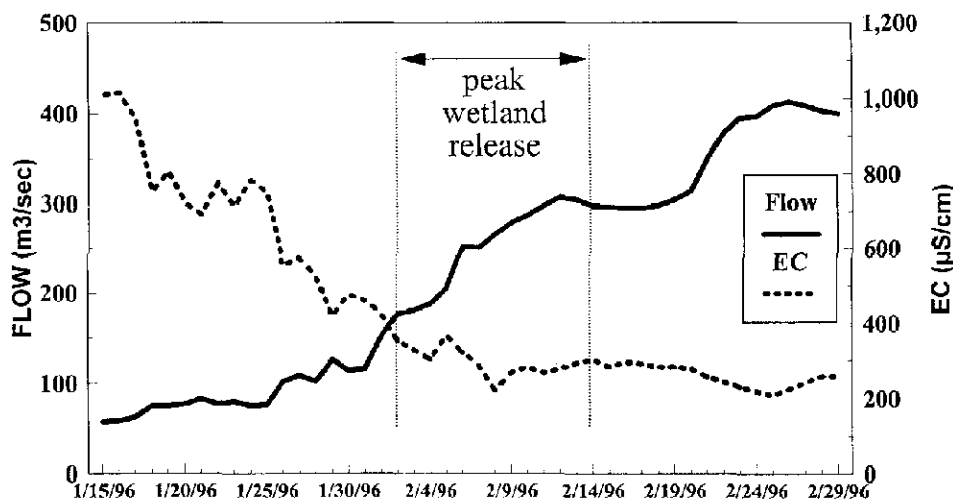
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Figure 7. Flow and Electrical Conductivity (EC) in the San Joaquin River Near Vernalis.

MANAGEMENT AND CONTROL OF AGRICULTURAL DRAINAGE

The most cost-effective agricultural drainage control structures allow storage of drainage effluent during periods of low assimilative capacity and discharge of drainage effluent during periods of high assimilative capacity. Drainage effluent is currently managed by the following techniques: (a) drainage source control and water conservation practices; (b) minimization of tailwater and separation of tailwater and tilewater; (c) recirculation and blending of subsurface drainage water; and (d) manipulation of subsurface drainage sumps. Implementation of these techniques requires intensive water management and require careful monitoring of salts.

The Grasslands Bypass Project, initiated in October 1996, is a unique program under which the agricultural water districts agreed to limit monthly and annual selenium loads from the 41,000 hectare DSA. A fee schedule for all exceedences of monthly and annual targets (with a cap of $250,000) was agreed after negotiations between the farmers, agricultural water districts, and the state and federal agencies participating in the project. Although the stringent monthly load limits currently constrain the flexibility of the water districts to adjust discharges to match river assimilative capacity, actions have been taken that will lead to improvements in future real-time management of discharges. A multi-million dollar investment by the participating water districts in flow

and EC monitoring systems, recirculation pumps and ditches, drainage storage facilities and sump control systems will allow centralized control of drainage discharges from each district outlet.

Source Control and Water Conservation

Water conservation practices have improved in each of the DSA water districts through the use of irrigation consultants, the implementation of tiered water pricing policies, and the organization of water management workshops for farm workers with instruction in both English and Spanish. Considerable improvements in on-farm irrigation practices have occurred over the last 12 months with investments in sprinkler systems and gated pipe to reduce losses associated with furrow pre-irrigation and conveyance in earth-lined ditches. Farmers in the DSA had found that irrigation efficiencies were poorest during pre-irrigation resulting from poor application uniformity.

Tailwater Return Systems

District policies that require all irrigation tailwater to be recycled and kept separate from subsurface drainage have improved on-farm irrigation efficiencies and reduced drainage volumes. One of the effects of implementing this policy has been to educate ditch

tenders and increase their understanding of the effect of management practices on irrigation distribution uniformity. As a result many fields have been subdivided and furrow row lengths reduced from 800 meters (1/2 mile) to 400 meters (1/4 mile).

Drainage Recirculation

The volume of subsurface drainage that can be recirculated is limited by the tolerance of the crop to salt and boron concentrations. Generally, when subsurface drainage is recirculated, it is blended with good quality surface supplies to minimize potential negative impacts on crop yield. Ample supplies of good quality supply water are needed periodically in an irrigation system where recirculated subsurface drainage is used (Rhoades,1984).

Manipulation of Drainage Sumps

Drainage sump pumps are typically activated when the water level rises above an electronic sensor located in the sump. The pump sensors would be overridden so as to shut off during periods of low river assimilative capacity and to turn on only when river assimilative capacity was adequate to accommodate drain flows. The manipulation of sump pumps has limited utility during periods of available assimilative capacity, i.e., during fall and winter months and in "wet" water years.

Regulating Reservoirs

One means of reducing the response time is to build regulating reservoirs, such as those considered in the planning studies, discussed earlier. During periods of low assimilative capacity, excess drainage is stored in the reservoir and later released when assimilative capacity becomes available. If these reservoirs were to be located close to the San Joaquin River storage could be manipulated to take advantage of short-term periods of high assimilative capacity. The experience at Kesterson Reservoir (Presser, 1994) and in the evaporation ponds of the Tulare Basin, California (Skorupa and Ohlendorf, 1991) have shown the potential danger of holding large volumes of selenium contaminated water above ground for extended periods of time. In both cases, bioaccumulation resulted in observable impacts to wildlife, even at low water column concentrations. Research and monitoring studies are needed to determine safe holding times in these reservoirs. These reservoirs should also be designed to minimize their attraction to wildlife by making them deep with steep shorelines, denuded of vegetation.

INSTITUTIONAL FRAMEWORK

For the real-time water quality management system to be fully implemented and successfully used by stakeholders, some institution building and reform at the state level will likely be required. Incentives need to be created for all parties for the acquisition, use and sharing of drainage and reservoir release data. Developing systems for dissemination of current information to interested parties is the first step and has been initiated through use of the Internet and the creation of an e-mail listserver for the project. The listserver automatically relays messages (including forecasts of real-time flow, water quality and scheduled reservoir release data) for downstream fisheries, flood control and recreation to the entire multiagency subscriber list.

A problem is created in this unstructured sharing of information in that it does not have a formal feedback loop – hence actions taken as a result of the flow and water quality forecasts gleaned from the listserver are not accounted for in the current system. For example, a downstream riparian diverter might increase pumping above typical seasonal levels from the San Joaquin River, if forecasts indicated a short term improvement in water quality. This action would decrease flow and salt load in the San Joaquin River reducing the accuracy of the Vernalis forecast. Forecasted Vernalis EC could increase or decrease depending on the location of the diversion and the relative salt concentration of the river relative to the Vernalis EC objective. One means of dealing with the feedback problem would be to set up specific schedules for issuing San Joaquin River water quality forecasts, and for issuing official updates to these forecasts, based on feedback information. To do this effectively will require the establishment of a central authority with responsibility for water quality in the San Joaquin River with control over drainage and reservoir operations. The current system has been in place for less than two years. It is envisaged that the technology transfer process and the loosening of institutional constraints will take several more years before the potential benefits of this system are realized. A research and development grant of $900,000 has been awarded to the SJRMP Water Quality Committee to continue development of the real-time water quality forecasting system over the next three years.

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Numerical Prediction of Precipitation and River Flow over the Russian River Watershed during the January 1995 California Storms
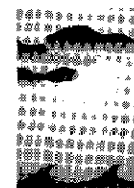
Norman L. Miller and Jinwon Kim

University of California Lawrence Livermore National Laboratory, Livermore, California

ABSTRACT

Precipitation and river flow during a January 1995 flood event over the Russian River watershed in the northern Coastal Range of California were simulated using the University of California Lawrence Livermore National Laboratory's Coupled Atmosphere-River Flow Simulation (CARS) System. The CARS System unidirectionally links a primitive equation atmospheric mesoscale model to a physically based, fully distributed hydrologic model by employing an automated land analysis system. Using twice-daily National Meteorological Center eta model initial data to provide the large-scale forcing to the mesoscale model, the CARS System has closely simulated the observed river flow during the flooding stage, where the simulated river flow was within 10% of the observed river flow at the Hopland gauge station on the Russian River.

1. Introduction

Predicting local precipitation, land surface hydrology, and river flow is important for early flood warnings and for efficient management of reservoirs. In mountainous areas such as the western United States, steep terrain and narrow valleys can cause severe flooding during heavy precipitation events. To prevent flooding, local reservoirs need to release stored water when heavy precipitation is expected. Therefore, inaccurate predictions of local precipitation and river flow can cause either unexpected flooding or unnecessary releases of water resources.

As part of an effort to investigate regional-scale atmospheric flows, precipitation, surface hydrology, and river flow at various temporal scales, we have developed a Coupled Atmosphere–River Flow Simulation (CARS) System. This modeling system can be used to forecast or diagnose both atmospheric conditions and land surface hydrology on regional to catchment scales. We applied the CARS System to a preliminary numerical prediction study over the Russian River Basin in the northern California Coastal Range during a flooding period in early January 1995. The following sections discuss the CARS System and the simulated precipitation and river flow.

2. The Coupled Atmosphere–River Flow Simulation System

The CARS System consists of three unidirectionally coupled numerical models: 1) the Mesoscale Atmospheric Simulation (MAS) Model, 2) the Automated Land Analysis System (ALAS), and 3) a modified version of the hydrology model known as TOPMODEL. As illustrated in Fig. 1, the CARS System can be nested within either a large-scale forecast or analysis data. Hence, the CARS System may be employed for predictions of regional weather and river flow or for simulating regional climatology, depending on the choice of the large-scale input data.

The unidirectional coupling occurs as follows. The MAS model simulates precipitation and atmospheric variables at a 20-km horizontal resolution using initial and time-dependent lateral boundary conditions

Corresponding author address: Norman L. Miller, Global Climate Research Division, University of California–Livermore, P.O. Box 808, Livermore, CA 94550.
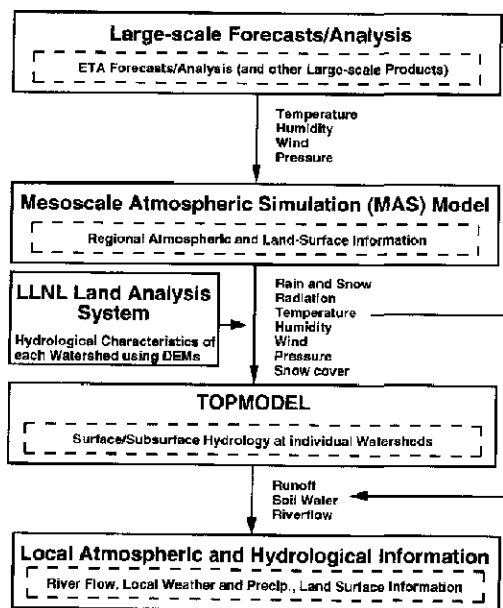E-mail: norm@llnl.gov
In final form 9 June 1995.

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Large-scale Forecasts/Analysis

ETA Forecasts/Analysis (and other Large-scale Products)

Temperature
Humidity
Wind
Pressure

Mesoscale Atmospheric Simulation (MAS) Model

Regional Atmospheric and Land-Surface Information

LLNL Land Analysis System

Hydrological Characteristics of each Watershed using DEMs

Rain and Snow
Radiation
Temperature
Humidity
Wind
Pressure
Snow cover

TOPMODEL

Surface/Subsurface Hydrology at individual Watersheds

Runoff
Soil Water
Riverflow

Local Atmospheric and Hydrological Information

River Flow, Local Weather and Precip., Land Surface Information

FIG. 1. Nesting procedure of the CARS System.

obtained from large-scale atmospheric input data. The simulated precipitation and atmospheric variables are then averaged over individual watershed areas computed by ALAS. TOPMODEL computes river flow using the watershed area mean precipitation and atmospheric variables simulated by MAS in conjunction with surface properties provided by ALAS.

The MAS model (Kim and Soong 1994) is a primitive equation, limited-area mesoscale model, which includes a third-order-accurate advection scheme (Takacs 1985) and physical processes for 1) precipitation and thermal forcing due to deep convective clouds and stratiform clouds, 2) solar and terrestrial radiative transfer within the atmosphere, and 3) turbulent transfer at the earth's surface and within the atmosphere. MAS directly computes rainfall and snowfall separately using a bulk cloud microphysics scheme by Cho et al. (1989). It also provides mixing ratios of cloud water and cloud ice that are used to determine optical properties of water- and ice-phase clouds for computing solar and terrestrial radiative transfer. Interactions between the atmosphere and land

surface are computed using the Coupled Atmosphere–Plant-Snow Model (Mahrt and Pan 1984), which has been fully coupled to MAS and has enabled us to keep track of available water resources, including those stored in the snowpack.

The Automated Land Analysis System is based on software developed by the United States Geological Survey (Jenson and Dominque 1988) and the Lawrence Livermore National Laboratory (Miller 1995). ALAS provides information on topographic properties such as river networks, watershed areas, and hydrologic characteristics at specified resolutions using digital elevation model data. The area and location of watersheds determined by ALAS are matched to the grid points of the MAS model, so that computed watershed area mean atmospheric variables and precipitation are available to TOPMODEL as input.

TOPMODEL is a physically based, fully distributed hydrology model. The conceptual version of TOPMODEL was initiated by Kirkby (1975), and the numerical model was developed by Beven and Kirkby (1979). TOPMODEL computes the soil water budget, surface–subsurface flow, and the volume of routed river flow in a specified area. It has been improved to include the effects of spatial scale on hydrologic processes (Sivapalan et al. 1990; Beven et al. 1988; Wood et al. 1990) and has been applied to many surface hydrological studies, including the effects of terrain on streamflow (Beven and Wood 1983) and the effect of climate change on hydrological processes (Wolock and Hornberger 1991). Our version of TOPMODEL has been further modified in that it is driven by atmospheric variables (precipitation, temperature, winds, and radiation) provided by the MAS model.

3. Precipitation and river flow simulations over the Russian River Basin

During January 1995, California received an unusually large amount of precipitation. Between 7 and 11 January, three consecutive, strong storms hit California. Several parts of the state were affected by high water, as the soils became saturated when the second storm reached the area. The Russian River Basin was among the areas hardest hit with an estimated flood-related damage of over $800 mil-

lion. We carried out a simulation of local precipitation and river flow during a flooding episode along the Russian River Basin in the northern California Coastal Range.

River flow simulations require separate inputs for rainfall and snowfall, since snowfall does not immediately affect river flows. The simulated 24-h accumulated rainfall and snowfall over the southwestern United States on 10 January 1995 are shown in Figs. 2a,b. The MAS model predicted heavy rainfall during this period along the northern Coastal Range, the western slope of the Sierra Nevada, and the southern California coast near Santa Barbara, which was also severely flooded. Rainfall to the north of the San Francisco Bay, including the northern part of the Russian River Basin, was particularly heavy. Since the snow line was located at approximately 2000 m (Fig. 2b), all of the precipitation that fell over the Russian River Basin was in the form of rain, which quickly saturated the soils and caused overland flooding.

Orographic features of the terrain in California cause strong spatial gradients in precipitation. To illustrate the importance of accurate estimations of local precipitation for computing river flows within mountainous terrain, we computed area mean daily precipitation over the entire Russian River Basin (3425 km²) and over the area within the Russian River Basin north of the Hopland gauge station (658 km²) during the simulation period. The terrain of the entire Russian River watershed and an enlargement for the region of the Russian River watershed north of the Hopland gauge station (hereafter Hopland watershed) are shown in Fig. 3. The simulated daily precipitation averaged over the entire Russian River watershed and the Hopland watershed frequently differs by a factor of 2–3, especially during the flooding stage (Fig. 4).

Figure 5 compares the simulated 6-h accumulated precipitation averaged over the Hopland watershed to the observed area mean precipitation, which is used to run the operational river flow model of the California–Nevada River Forecast Center. These observed area mean precipitation data are based on four rain gauge values from Willits, Ukiah, Yorkville, and Lake Mendocino (Fig. 3). A weighting function based on climatological rainfall distribution within the Hopland watershed (E. Strem 1995, personal communication) gives observed area-averaged precipitation of these areas as
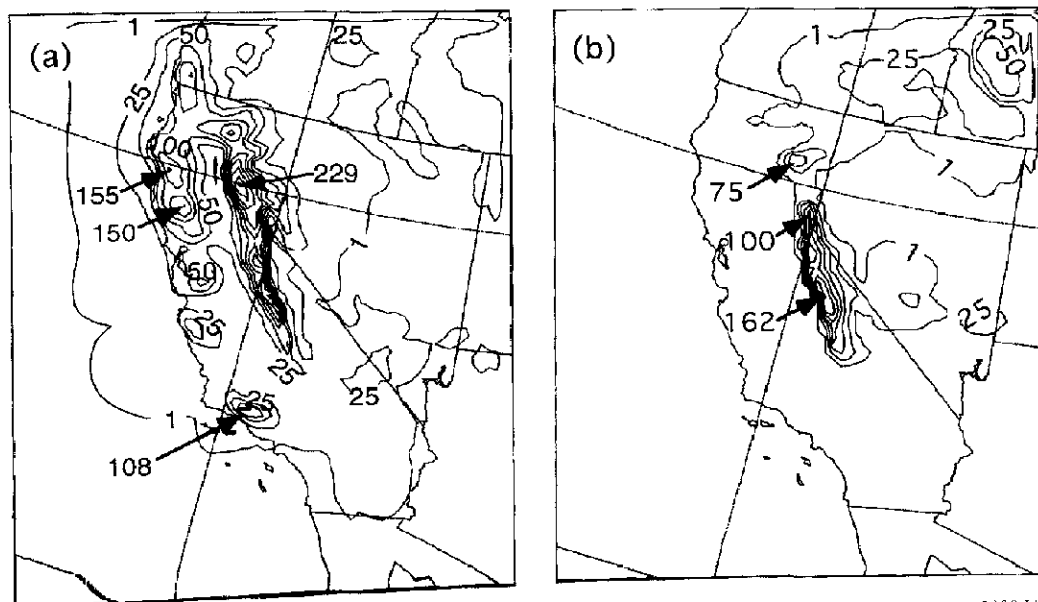

Fig. 2. A 24-h accumulated (a) rainfall and (b) snowfall, in equivalent water depth, forecasts for 0000 UTC 1 September–0000 UTC 1 October 1995 over the model domain. Units are in mm day⁻¹. The contour interval is 25 mm.
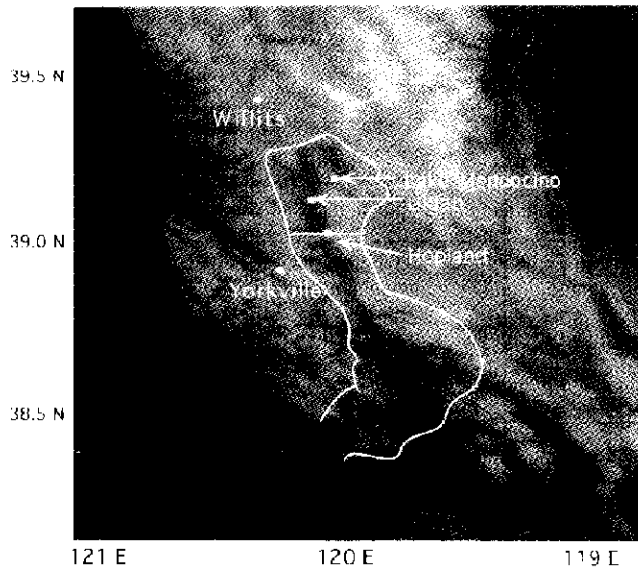
Fig. 3. Terrain and watershed boundary of the Russian River Basin at a 250-m resolution. The Hopland watershed is located north of the 39°N parallel (indicated by a solid east–west line at Hopland) within the Russian River Basin.

$$\overline{P}_{\text{Hopland}} =$$
$$0.22 P_{\text{Willits}} + 0.28 P_{\text{Ukiah}} + 0.23 P_{\text{Yorkville}} +$$
$$0.28 P_{\text{Lake Mendocino}},$$

where $\overline{P}$ and P are area mean and single rain gauge values, respectively. The simulation has well captured the amount and timing of precipitation over the Hopland watershed during the study period, except on 10 January where the model significantly overestimated the observed precipitation. This overestimation was due to a large amount of moisture influx into the area prescribed by the eta model initial fields.

In this study, soil texture, topography, and the initial soil water saturation deficit were the most important surface properties for computing river flow. The initial soil water content for this simulation was obtained by running TOPMODEL with the observed climate history prior to the January 1995 storms. Watershed properties for the Hopland Basin were computed at a 200-m resolution using topographic elevation data at a 100-m resolution, as sensitivity studies indicated that this resolution is sufficient for the region.

Figure 6 illustrates the observed and simulated daily mean river flow volume at the Hopland gauge

station from 1 to 12 January 1995. The CARS System simulated the river flow rate within 10% accuracy during the flood stage. A significant overestimation of the modeled river flow for 11 January was due to overpredicted rainfall on 10 January. The simulated river flow exceeded the observed river flow by approximately 30% during low flow periods before flooding mainly due to the uncertainties in the initial soil water content.

4. Conclusions

We have developed a Coupled Atmosphere River Flow Simulation System by coupling a mesoscale atmospheric model with a physically based, distributed hydrologic model that simulates regional precipitation, mesoscale atmospheric circulations, surface hydrology, and river flow. This prototype system successfully modeled the January 1995 storms that caused severe flooding along the Russian River watershed in the northern California Coastal Range. The simulated area mean precipitation is in strong agreement with the observed precipitation. The simulated river flow is also in strong agreement with the observed value at the Hopland gauge station along the Russian River, as the simu-
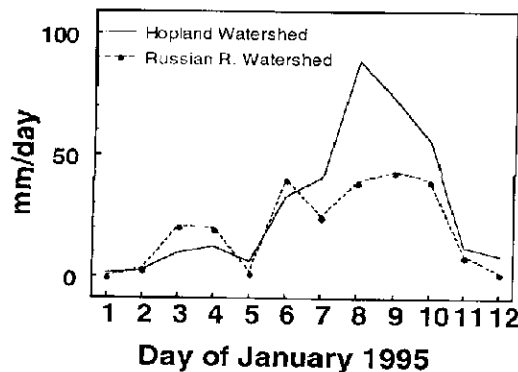

Fig. 4. The simulated area mean precipitation over the entire Russian River watershed (dashed line with solid circles) and over the Hopland watershed (solid line).
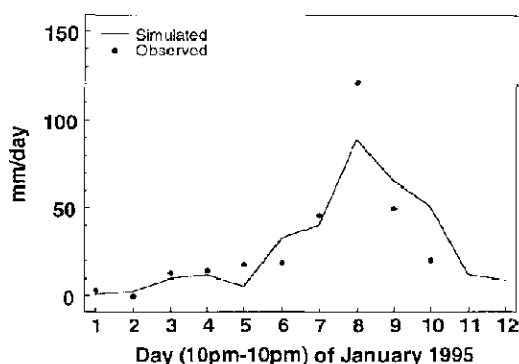
Fig. 5. The observed (circles) and simulated (line) area-averaged, 6-h accumulated precipitation over the Hopland watershed.
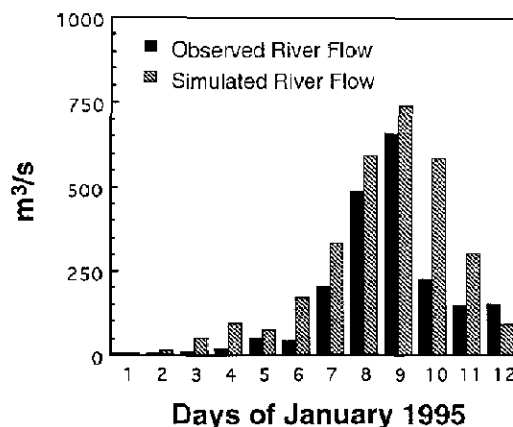

Fig. 6. The observed (solid bar) and simulated (shaded bar) river flow rate at the Hopland gauge station.

lated river flow during the flooding period differs from the observed value by 10%.

The CARS System is currently being employed for experimental numerical weather prediction for the southwestern United States. We have successfully run this system continuously from 1 January to 30 March with a similar accuracy level. These results are being prepared for a more detailed manuscript. The hydrologic simulation component of the CARS System is being extended to include several other major river systems within California, including the Lake Shasta inflow, the American River, and the Feather River.

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